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IMPROVING HYDROMETRIC SYSTEMS

INSTITUTIONAL AND TRAINING ASSESSMENT FOR HYDROLOGICAL MONITORING

February 2005

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Acronyms and Abbreviations

ADCP	Acoustic Doppler Current Profiler
DCP	Data Collection Platform
DNA	Direcçao Nacional de Águas, Angola
DRH	Departamento Recoursos Hídricos a DNA department, Angola
EPSMO	Environmental Protection and Sustainable Management of the Okavango River Basin Project
ERP	Every River Has Its People Project
GABHIC	Gabinete para Administração da Hidrografia da Bacia do Rio Kunene, Angola
GAMEK	Gabinete de Aproveitamento do Médio Kwanza, Angola
HYCOS	Hydrologic Cycle Observing System
HYDATA	Hydrological Database, a specialized database software package used in Botswana and Angola
Hydstra	Hydrological database, a specialized database software package used in Namibia
OBSC	Okavango Basin Steering Committee
OKACOM	Okavango River Basin Water Commission
SADC	Southern African Development Community
USAID	United States Agency for International Development

Preface

The USAID/OKACOM Okavango River Basin Project, a four-year initiative is coordinated by the Permanent Okavango River Basin Water Commission (OKACOM) and funded by USAID/Southern Africa. The Project collaborates with OKACOM and its technical advisory committee, the Okavango Basin Steering Committee (OBSC), as well as government ministries, active non-governmental organizations in the basin, communities, regional academic and research institutions, and businesses and local government institutions that use and manage the resources in the Okavango River Basin. ARD, Inc. implements this initiative.

This report presents the results of an assessment of approaches to conduct hydrological monitoring, use and manage information at responsible institutions in Angola, Botswana and Namibia. Based upon the assessment, a training action plan for improving monitoring within the three countries with a particular focus on the Okavango River basin was prepared and is included in this report. This assessment was conducted in October 2005 and results summarized for the 11th Meeting of the Permanent Okavango River Basin Water Commission, held in Windhoek the first week of November 2005. This report was prepared by Jon Hodgkin, Senior Integrated Water Resources Specialist from ARD. Mr. Hodgkin and the senior hydrologists from Angola, Botswana, and Namibia visited representative monitoring stations in all three countries and the training action plan included in this report was developed by this team.

The USAID/OKACOM project team would like to express warm thanks to Paulo Emilio Mendez of the Direcçao Nacional de Águas in Angola, Kalaote Kalaote of the Department of Water Affairs in Botswana, and Guido Van Langenhove, of the Department of Water Affairs in Namibia, who spent time with the Mr. Hodgkin answering endless questions and organizing field trips to surface water monitoring sites, a three day trip in the case of Namibia. Their candor and honesty was appreciated and without it, this report could not have been completed.

The author thanks others who provided guidance, review and comment to this work. This includes Scott McCormick, the USAID/OKACOM Project Chief of Party; Nancy Kgengwenyane, Deputy Chief of Party, who helped organize the consultancy; Alisdair McDonald of the Okavango Delta Management Project who provided information and review; Olav Osvall who provided insight on activities in Angola; and Joaquim (Buca) Boavida who served as a guide and translator in Angola; and the rest of the USAID/OKACOM Project staff who made work pleasant and enjoyable. Please note that any errors contained herein are the sole responsibility of the author and the views expressed are the author's alone.

Executive Summary

SCOPE AND APPROACH

The purposes of this consultancy, with respect to the Okavango River Basin, were 1) to review approaches to hydrological information collection, use and management at lead government institutions in Angola, Botswana and Namibia, 2) to assess current capacity including organizational relationships, staffing levels, and budgeting processes, and 3) to develop a training action plan for improving monitoring within the three riparian countries. The approach taken was to visit the three riparian countries, review available documentation, and interview the staff of key water agencies. The resulting training action plan takes advantage of best practices within the three countries, focusing first on what could be accomplished using existing experiences and skills, and what could be reasonably continued following project completion. Through a closer examination of operational requirements in the Kubango catchment in Angola, this assessment developed specific recommendations for training related to operation and maintenance of equipment purchased by the regional USAID River Basin project.

FINDINGS: ANGOLA

Angola has more water resources nationally than Namibia and Botswana combined. The *Departamento Recoursos Hídricos* (DRH) within the *Direcçao Nacional de Águas* (DNA) used to manage more than 180 stations nationwide, with 13 stations in the Kubango catchment. Following more than 25 years of conflict, it has 11 stations nationwide. Angola has relatively complete hydrologic records for the Kubango catchment from the middle to late 1950s until 1974-75. With support from the Norwegian Agency for Development Cooperation, the *Departamento Recoursos Hídricos* has digitized and checked 10 years of data for more than 150 stations, including 13 in the Kubango catchment. Thus valuable historical data do exist.

Today, the *Departamento Recoursos Hídricos* is working to reestablish hydrometric monitoring for select stations using modern electronic data logging instruments. Most if not all of this work has been financed through the Norwegian supported National Water Sector Management Project, which ended recently. New stations are being equipped with data logging instruments, including the Hydrologic Cycle Observing System (HYCOS) Data Collection Platforms, OTT Thalimedes data logger, and one OTT pressure probe. Angola also has OTT C-31 current meters and an Acoustic Doppler Current Profiler (ADCP) for gauging, rating and determining discharge. Some fifteen more OTT Thalimedes are ready for installation in the Kunene and Katubela catchments and other locations in the north. USAID, through the Okavango project, is also planning to provide instrumentation for five stations in the upper Okavango River basin. This is the result of recommendations from a three-country Stakeholder Workshop, an Angola reconnaissance of April 2005, and subsequent meetings with hydrologists from the three riparian countries. Following the completion of the National Water Sector Management Project, little data have been downloaded from data loggers, as the *Departamento Recoursos Hídricos* lacks the resources to visit the field. All training for the eight Technicians[1] employed by the *Departamento Recoursos Hídricos is* ad-hoc through donor financing.

[1] Techicians and Technical Assistants are positions within the government departments of the three countries, and therefore, capitalized in this report.

FINDINGS: BOTSWANA

Botswana has been monitoring water resources in the Okavango Delta for 72 years when the first discharge measurements were made at Mohembo in 1933. Since then the Hydrology Division of the Department of Water Affairs has established flow and water level monitoring stations throughout the Delta, some permanent with relatively long records. Hydrologic monitoring equipment and procedures still depend largely on visual observation of stage with chart recordings. At Mohembo, river gauging and discharge measurements are made daily. Within the Delta, the hydrology is complex and still not well understood. Evapo-transpiration and infiltration are important factors that could be better characterized. Flow rates in the lower Delta are low, and discharge measurements difficult to make and understand. The Department of Water Affairs manages hydrometric monitoring in the Okavango and its Delta from regional offices in Maun and Gumare, with dedicated staff in both locations and at a permanent camp at Mohembo. They collect and process data at regional offices and transmit to Gaborone annually for most stations, and weekly for six important ones. The technical staff, led by the Supervising Chief Technical Officer, is in charge of data collection and processing, with hydrologists reviewing the data only when they use the data. Primary data can be modified at any time if hydrologists or other data users find problems or errors. The Department of Water Affairs understands the potential for modern digital data collection, but is cautious about making commitments, given recent experience which includes poor performance of first generation equipment, vandalism, and wild animal damage. The Okavango Delta Management Plan has plans to improve the hydrologic instrumentation network by procuring and installing 27 digital water level recorders. Although the Department of Water Affairs' training program for Technicians is well defined, field staff, especially artisans, could benefit from further training regarding what the data they collect is used for and why accuracy is important.

FINDINGS: NAMIBIA

Namibia perennial rivers are few, with the Kavango River as one of the most important. The Hydrology Division of he Department of Water Affairs and Forestry (DWAF) is responsible for hydrometric monitoring. It manages important gauging stations at Rundu (established in 1945) and Mukwe (established1949). Hydrology Division staff include 3 managers, 10 Hydrologists and Technicians and 20 Technical Assistants, and are stationed in Windhoek. They are responsible for monitoring at some 105 stations nation-wide, with station visits to the Okavango gauging stations requiring a drive of some 700 km. The Division's goal is to visit each station at least once every 3 months by sending teams on circuits around the country. Difficult logistics and budgetary constraints limit the time that staff can spend at each station. Also, with so few perennial rivers, most have little opportunity to develop skills in discharge measurement. The Hydrology Division is in the process of evaluating and installing OTT data loggers and now have both data loggers and chart recorders installed at Rundu and Mukwe. There are less than 10 digital water level data loggers in the country now, but indications are that the future for data collection is digital if these systems prove reliable and as spare parts for older chart recorders become harder to find. Collection, verification, and archiving appear to be rigorous, with concerted efforts to ensure data accuracy and reliability. Formalized procedures including use of specialized data collection forms are in place and appear to be followed. The process of checking and rechecking data before final entry into the hydrologic database appears to be more thorough than elsewhere in the basin. Most training for technical staff is on-the-job following short focused training courses of a week or less. Field training with oversight and correction of technical work is provided by hydrologists and senior technicians.

GENERAL CONCLUSIONS:

Hydrologic monitoring in all three riparian countries in the Okavango River basin is being managed by a division of the national agency responsible for water resources management. Much, if not all, field work related to hydrologic monitoring, is the responsibility of hydrometric Technicians and Technical Assistants. This includes making level readings, replacing level recording charts, downloading data loggers, and completing river gauging. Logistical factors weigh heavily on how they collect data. Scarcity in mid- level professional staffing is also noted. In Angola, the Director of the *Departamento Recoursos Hídricos* has knowledge and experience with the country's hydrologic monitoring that is unparalleled, and he will be eligible to retire within the next several years leaving a Department with no obvious successor and no one with his experience and skills. Identifying and training hydrologists should be a high priority for Angola. Similarly, in Namibia several of the senior managers will be eligible to retire soon. A more formal mentoring program for younger Namibian hydrologists, if not already established, should be

implemented to ensure capacity exists into the future. In Botswana, the Department of Water Affairs' professional hydrologists are not routinely assigned to review, correct, or edit data as part of regular support for the data management process. Hydrologists should be given more responsibility for ensuring that data are checked and verified before it is archived in the database.

Qualifications and training for Technicians are different in each of three countries. The national requirement for hydrometric Technicians is not sufficient to justify a specialized course in any of the three countries. As a result, even the most qualified entry level Technicians need additional training related to hydrology and hydrometry. Such training or has been a feature of all training programs with the most regular training taking place in Botswana. Namibia does not hire many new Technicians and does not find it cost effective to run regular courses, so teaches courses on an as needed basis. In Angola, all in-house training stopped some ten years ago due to constraints imposed by the war. A participatory review of the three in-house Technician training programs could provide an opportunity for each department to compare training programs and adopt best practices for the benefit of Technicians.

Technical Assistants (or artisans as they are referred to in Botswana) are non-Diploma staff (they did not complete secondary school). In Angola, the distinction is not made formally, but younger, less experienced Technicians are recognized as such, and are supervised by more senior Technicians. This group provides the core of staff that go to the field on a day-to-day basis to visit gauging stations and collect data. The reliability and accuracy of their work is critical to the hydrologic data collection process. Training for this group is entirely in-house, with classroom training provided by department Hydrologists or Technicians. Technical Assistant training that improves skills and enhances pride in field performance is critically important and should improve data quality.

Instrumentation in use is slightly different in the three countries, with Angola making the biggest commitment to digital data collection. With nearly all stations in the country needing repair and upgrading, the opportunity to move decisively toward modern data collection techniques was seen and taken. Botswana, while an early convert to digital data collection in the 1990s, found that first generation digital data collection equipment was not reliable and have until now relied largely on staff gauges and chart recorders. However, there is agreement that digital equipment, if reliable, would be a step forward. Namibia has taken a middle course, with the recent introduction and trial of digital data loggers. These are being run in parallel to chart recorders to test reliability while ensuring data collection. These different experiences suggests that opportunities exist for Technicians to be exposed to new equipment and learn from the experiences of the others before making expensive equipment decisions.

One regional training opportunity exists in the regional Hydrologic Cycle Observing System (HYCOS) Project. Much of its training is associated to the installation, operation, and maintenance of the HYCOS Data Collection Platforms. In addition, the Implementing Agency (the Department of Water Affairs and Forestry in South Africa) offers a two week introduction to hydrometry and specific hydrometry training modules at their facility near Pretoria.

RECOMMENDATIONS: TRAINING

Visits to each country revealed that training needs within the three countries are related but slightly different. In Angola, no training program currently exists and a broad modular training program should be designed to replace the ad hoc training that takes place now. The overall program should include a) basic hydrological principles, b) methodological training for Technicians, c) use of digital hydrometric instrumentation, d) gauging techniques and use of current meters, e) care and use of the Acoustic Doppler Current Profiler current profiler, f) project planning, budgeting and management, and g) computer training. However, before such training can be carried out effectively, additional staff should be engaged. In spite of the lack of a formalized training program, the hydrological monitoring staff would benefit from additional specific training as follows:

- Additional training in the installation and set up for Thalimedes data loggers,
- Gauging techniques and use of the OTT C-31 current meter,
- Care and use of the Acoustic Doppler Current Profiler (which may be covered as a contribution from the Norwegian Project),
- Development and training in the use of data collection forms and procedures
- English language training.

In Botswana, the Department of Water Affairs has a formal training program for Technicians and Technical Assistants (Artisans). It is important that these programs be offered on a regular basis and that refresher courses focus on data collection issues that arise. Beyond this basic training, the following four specific training needs were identified:

- Awareness of the importance of hydrologic data for Artisans and Gauging Assistants,
- Installation, use and maintenance of digital hydrologic monitoring equipment,
- Maintenance and repair of chart recorders, and
- Data evaluation, verification, processing, and editing.

Training is a major concern and a focus for the Hydrology Division in Namibia. Upgrading field and office skills through supervision, review, and assessment of work products is the principle training method. Additional training needs include:

- Basic hydrology and hydrometric monitoring for Technicians
- Installation, use and maintenance of OTT Thalimedes data loggers,
- Awareness of the importance of hydrologic data for Technicians and Technical Assistants, and
- Current gauging using conventional current meter methods and the Acoustic Doppler Current Profiler.

The recommended ***Training Action Plan*** (to be approved by OKACOM) derives from interviews and field visits, discussions with Hydrologists, Technicians, and Technical Assistants, and focused consultation with the Hydrologists of primary responsibility in each country. Consensus was readily reached that re-establishing hydrometric monitoring in the Angolan part of the basin was the first priority and a second priority was to complete rating exercises to allow discharge calculations for new stations in Angola and improve calculations for existing stations in Namibia. Consensus was also reached regarding the benefit of Technician and Technical Assistant cross visits as a way to observe and develop skills and improve hydrometric practice. All believed that focusing on Technicians and Technical Assistants would help raise the profile of the work they were performing, provide incentives for reliability and accuracy, and help engender pride in the critical part they play in collecting and processing the information required for basin-wide planning. As a result, the training action plan focuses first on establishing monitoring in the Kubango catchment in Angola, and providing training to Technicians to be hired to support basin monitoring, second on providing opportunities for monitoring professionals and Technicians to observe and learn from best practices though cross visits and joint field exercise, and finally provide targeted training to support expressed training needs in each country as resources allow. A tabular summary of the proposed Training Action Plan is provided below.

Table 1: Proposed Training Plan -- Summary

Training program	Instructor (s)	Target Audience	Course Duration	Venue
Regional Training				
ADCP Joint Demonstration and Measurement	Paulo Emilio de Mendez and Angolan Technicians	Hydrologist and 2 Technicians from each country	Three weeks	River locations in Angola, Botswana and Namibia
OTT Thalimedes installation and use	Chief Technician DRH, Angola	Technician and 2 Technical Assistants each country	Two weeks	Five new gauging stations Kubango catchment
River gauging practical	Technician in charge, DWA/Botswana Mohembo camp,	2 Technician and 2 Technical Assistants each country	Two weeks	DWA Camp, Mohembo Botswana
Hydrologic data processing and archiving	Hydrology Division staff, DWAF, Namibia	2 hydrologists from each country	One week	DWAF offices, Windhoek
Angola				
New Technicians- *Methodological training*	*Paulo Emilio de Mendez*	*New Technicians hired for Kubango catchment monitoring*	*Two weeks*	*Luanda, DRH offices*
New Technicians- *Kunene Province Practical*	*Chief Technician DRH, Angola*	*New Technicians hired for Kubango catchment monitoring*	*One month*	*Field sites in Kunene Province*
New Technicians*- Computer skills training*	*TBD*	*New Technicians hired for Kubango catchment monitoring*	*TBD*	*Menongue if possible*
New Technicians-*Field installations and initial discharge measurement*	*Chief Technician DRH, Angola*	*New Technicians hired for Kubango catchment monitoring*	*Two weeks*	*Field sites in Kubango catchment*
New Technicians- *Follow-up training and support*	*Chief Technician DRH, Angola*	*New Technicians hired for Kubango catchment monitoring*	*One week on three occasions*	*Field sites in Kubango catchment*
River gauging using the OTT C-31 Molinete	Chief Technicians DRH, Angola	Recently hired Technicians	Two weeks	Selected river sites near Luanda
English Language Training	Language training institute	Recently hired Technicians	TBD	Luanda and/or Provincial towns
Botswana				
Digital instrument care and maintenance	Senior Technical Officers and/or manufacturer's representatives	Technicians, Artisans and Gauging Assistants	One week	DWA Training Center
Improved awareness of data use	ODMP Modeling staff	Artisans and Gauging Assistants	Two days	Field offices in Maun and Gumare
Namibia				
Awareness and motivational training	DWA/Botswana hydrology Division modeling unit	Technicians and Technical Assistants	Two days	DWAF offices, Windhoek

Also, USAID/OKACOM should consider sponsoring additional Technicians for Hydrologic Cycle Observing System (HYCOS) training to ensure that trained HYCOS Technicians are available within each country. If these courses are seen by national hydrology departments to meet specific basin hydrometric training requirements, USAID/OKACOM should consider sponsoring attendance at one or more of the short courses or training modules.

1. BACKGROUND

Water scarcity in Southern Africa is a growing concern. Population growth and associated demands for domestic, agricultural, and industrial use are increasing stress on limited water resources. The majority of the region's watersheds are shared between two or more countries. What happens in the upper reaches of rivers and watersheds affects people, wildlife and ecosystems downstream. Regional responses and coordination are required to insure equitable allocation and use of water resources within river basins.

Angola, Botswana, and Namibia agreed in 1994 to establish the Permanent Okavango River Basin Water Commission (OKACOM) to promote coordinated, regional water resources development objectives for the Okavango river basin, while addressing the legitimate social and economic needs of these three riparian states. A coherent approach to managing the basin's resources, based upon equitable allocation, sound environmental management, and sustainable utilization is a key objective of OKACOM's efforts.

USAID/Southern Africa, recognizing the commitment of OKACOM, has agreed to support the commission's institutional development through the Okavango River Basin Project, a four year, US$6.6 million initiative. OKACOM and its technical advisory body, the Okavango Basin Steering Committee (OBSC), will implement the Project in collaboration with government ministries, active non-governmental organizations in the basin, communities, regional academic and research institutions, businesses and local governments that use and manage the resources in the Okavango River Basin.

The USAID/OKACOM Okavango Project combines efforts with other basin-wide initiatives, such as the Environmental Protection and Sustainable Management of the Okavango River Basin Project (EPSMO), financed by the UNDP-Global Environment Facility and the Every River Has Its People Project (ERP), supported by the Swedish International Development Cooperation Agency in the implementation of improved river basin management activities.

Three components make up the Project*: organizations' ability to manage river basin resources enhanced; information systems for biodiversity and natural resource management improved, and; improving community management and local governance of natural resources*. These three distinct but interrelated components combine synergistically to strengthen regional capacity for improved management of selected river basins. Incorporated with these three components are three cross-cutting themes – highlighting HIV/AIDS within the basin, ensuring the participation of women and disadvantaged groups, and promoting the participation of the private-sector, through the development of public private partnerships.

The USAID/OKACOM Project has been operating since October 2004. This report was prepared in support improved information systems for biodiversity and natural resource management by outlining a training program for improved operation of the hydrometric network in the Okavango basin.

1.1 PURPOSE

The purpose of this consultancy was to define and review approaches to hydrological information collection, use and management at the responsible institutions in each country – The National Directorate of Water in the Ministry of Energy and Water Affairs in Angola, the Department of Water Affairs in the Ministry of Minerals, Energy, and Water Affairs in Botswana, and the Department of Water Affairs and Forestry in the Ministry of Agriculture, Water and Rural Development in Namibia. The particular focus was on water resources information as it relates to the Okavango River basin, and on developing a training action plan for the USAID/OKACOM Project as part of it's contribution to improving water resource data systems that will be required to complete the Transboundary Diagnostic Analysis and evaluate technical proposals for developing the water resources of he basin.

Since a fundamental goal of the Project is to build local capacity, the consultant maximized inclusion of local counterparts in all discussions and discussed findings and recommendations for each country with representatives

from all three riparian states as a way to increase regional knowledge and understanding. Specifically, the consultant worked in close consultation with the principle Hydrologists in each of the three riparian countries.

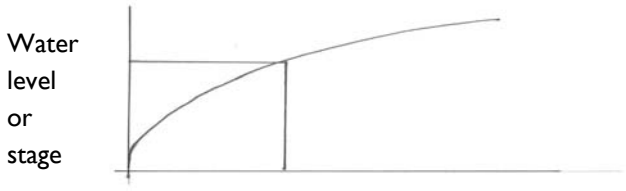
1.2 APPROACH AND METHODOLOGY

The Consultant's approach to completing the assignment was to visit the three riparian countries, review available documentation and interview the staff of the water agencies responsible for hydrometric monitoring - the Departamento Recoursos Hídricos (DRH) of Direcçao Nacional de Águas (DNA) in Angola, the Division of the Hydrology and Water Resources of the Department of Water Affairs in Botswana and the Hydrology Division of Department of Water Affairs and Forestry in Namibia. Interviews included both professional technical staff[2]. Field visits to hydrologic monitoring sites to see instrumentation and assess field operations were undertaken in each country (see Appendices 2 and 3). The goal of this process was to define the institutional setting including organizational relationships, staffing levels, and the budgeting process to establish current capacity to support water resources monitoring in the three countries. Identification of specific instrumentation used and detailed data collection, verification, and archiving procedures provided was required to identify practices that might benefit other countries and weaknesses that might be addressed through training. From this examination, conclusions were reached and a training action plan developed. The training action plan was developed within a framework that focused on taking advantage of best practices within the three countries, looking first on what could be accomplished using existing experiences and skills and what could be reasonably continued following Project completion. A closer examination of operational requirements in the Kubango Catchment[3] resulted in a specific program to begin the process of training Technicians to operate and maintain equipment that will be purchased by the Project to reestablish monitoring in the upper part of the basin. This specific program is outlined in Appendix 4 and included in the table describing the training action plan (Table 7.1)

1.3 PRINCIPLES OF HYDROLOGIC MONITORING AND RATIONALE FOR SUPPORT

Among the most important water resource management tasks within any river basin is the determination of the usable water resources (the resources available after environmental flows have been established, agreed upon, and accounted for), and how those resources are to be allocated among users and in the case of transboundary river basins-among countries as well. This requires that total water resources are measured as accurately as possible, accounting for wet and dry periods and the availability of resources. This is never a perfectly accurate process but a highly sophisticated one that uses available data and statistical analysis to determine probabilities for water levels, flows, and availability at various locations in the basin. Accurate data are a requirement for reliable estimation of available resources. With accurate data collected over longer periods of time, these estimations become more precise. The hydrologic data sets currently available for the basin provide a starting point, but continued data collection, particularly for the Kubango catchment in Angola, is important for understanding basin hydrology and refining current estimates for water resources.

Figure 1.1: Stage-Discharge or Rating Curve



Water resources measurement in river systems is a process that depends on determination of flow rates (discharge) at defined locations over long periods of time. The measurement process depends on understanding the relationship between water level and flow rate at important locations such as the confluence of tributaries, or in the case of the Okavango Delta, where the Okavango River enters the Delta. Hydrologic monitoring stations (gauging stations) are normally placed at locations where the river channel is stable so that the river cross section does not change significantly over time. Water level readings are taken continuously or on a periodic basis as

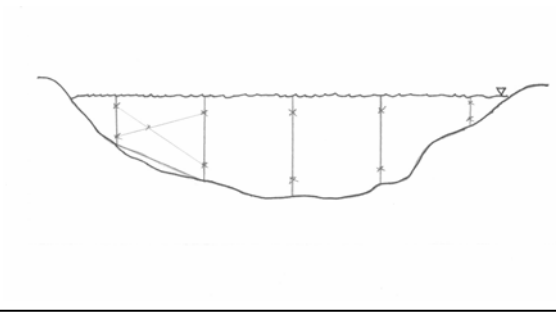
[2] See Bibliography for a listing of documents reviewed and Appendix 1 for a list of those interviewed

[3] The Kubango Catchment is one of Angola's 77 defined catchments and includes the Kubango and Kuito River basins that makes up the Angolan part of the Okavango River basin.

often as hourly in some cases, but daily and sometimes even less often using visual inspection of a gauge plate or staff gauge, paper chart on a chart recorder or digitally with a data logger. To relate water levels to flow, hydrologists develop a rating curve (see Figure 1.1) that allows one to estimate discharge based on water level.

In order to create the rating curve, hydrologists calculate flow for a variety of water level conditions. This process, called gauging, requires that the river cross section is defined and water velocities measured. The process is defined by accepted international standards that require depth readings to be taken in a line that crosses the river, creating an estimated cross section, and then taking water velocity readings with a current meter at several depths as shown in figure 1.2. The simplest method for calculating flow rates is to average velocities on the sides of each trapezoidal cell and multiply by the area to arrive at an average flow through each cell. By summing the flows in each cell, an estimate of total discharge is determined. A recent technological innovation, the Acoustic Doppler Current Profiler (ADCP) uses physical principles to allow automatic calculation of velocities and flows. This gauging process, whether by traditional current meter or ADCP, provides one point on the rating curve shown in Figure 1.1. When the water level is higher, the river cross section is larger and average water velocities are higher so that multiple gauging at different water levels are required to derive an accurate rating curve. Once a rating curve has been developed for a gauging station, periodic gauging is still required to confirm that the river cross section has not changed significantly and the stage-discharge relationship is still valid.

Figure 1.2: Measuring Discharge



Given the constraints imposed by geography, climate, staffing, equipment availability, etc., gauging exercises might not be conducted often. At some locations, level readings at a stable section may be taken on a regular basis and discharges determined at a later time after gauging has taken place. At other locations, discharge is based on gauging and rating curves that may be decades old. This does not mean that estimates are wrong, only that care must be taken in interpreting and using the data. The fact that no recent data (water levels or discharge) exists for the Kubango catchment is a significant concern for hydrologists and water resource planners alike. Reestablishing gauging stations and initiating hydrologic data collection in the Kubango catchment was highlighted by the USAID/OKACOM Okavango Project Strategic Action Planning workshop held in February 2005 and stated as a priority action to provide a better understanding of basin hydrology and allow more accurate estimation of basin water resources.

2. RELEVANT REGIONAL AND NATIONAL PROJECTS

A number of regional and national initiatives taking place within the Okavango River Basin are important to the USAID/OKACOM Project. There are three that have direct relevance to hydrologic data collection. These are SADC-HYCOS Phase II, the UNDP-GEF Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO) Project, and the Okavango Delta Management Plan Project. These are briefly described below.

2.1 SADC-HYCOS PHASE II: CONSOLIDATION AND EXPANSION OF THE HYDROLOGIC CYCLE OBSERVING SYSTEM IN THE SADC SUB-REGION

The SADC-HYCOS Phase II Project builds on the experience gained during the SADC-HYCOS Phase I Project (1998-2001). The Phase I Project supported joint hydrological and meteorological data collection and improved coordination and data sharing among Southern African Development Community (SADC) member countries. The project procured and installed[4] some fifty Data Collection Platforms (DCPs) utilizing satellite telemetry to allow remote access to the data collected and established a Pilot Regional Center in Pretoria to download the data and make it available through internet connection to national agencies, regional organizations, and others. Two DCPs installed during Phase I of the project are located in the Okavango River basin[5]. At this time data are not available on the Pilot Center's website and many of the stations are not operating properly. Equipment issues raised included Hydrologic Cycle Observing System (HYCOS) project insistence in uniformity of DCP packages, poor siting for some parameters (short sensor cables, areas protected from prevailing winds so that wind speed measurements were not representative, etc.), frequent failure of pressure probes used to measure water level, and failure (or inability) to post data to the website.

Phase II, initiated in July 2005, will seek to learn from pilot phase problems and will have four distinct components: 1) Improve the network of hydrological observing stations, 2) continue development of the sub-regional and national water resources information systems, 3) identify and develop hydrological products of regional interest, and 4) training and awareness building. The Project anticipates repairing the DCPs installed under Phase I as needed[6] and procuring about 100 new DCPs for placement so as to "serve the broader regional aspects of water resources assessment and hydrological forecasting". The Project also anticipates training in installation, maintenance and operation of this equipment. It is not clear if any of these new DCPs will be allocated to the Okavango River basin, but a strong argument should be made that several be placed in Angola along the Kubango and Kuito Rivers. The USAID/OKACOM Project should coordinate training with the SADC-HYCOS Phase II Project and consider sponsoring selected Technicians from Angola, Botswana, or Namibia to expand he number who have the skills required for operating and maintaining this equipment.

2.2 ENVIRONMENTAL PROTECTION AND SUSTAINABLE MANAGEMENT OF THE OKAVANGO RIVER BASIN (EPSMO) PROJECT

The Environmental Protection and Sustainable Management of he Okavango River Basin (EPSMO) Project is a UNDP-GEF project designed to alleviate imminent and long term threats to the linked land and water systems of the Okavango River through joint management of Okavango River Basin Water Resources and protection of linked aquatic ecosystems and their biological diversity. The Project's two components are A) strengthened mechanism for joint management of the Okavango River Basin and B) completed trans-boundary diagnostic assessment. One activity under component B is to complete a water resource assessment and analysis, a requirement for completing the transboundary diagnostic assessment. This could not be completed without

[4] Four of the stations in Angola were eventually installed by the National Water Sector Management Project

[5] Mohembo, Botswana and Rundu, Namibia

[6] It should be noted that a common problem has been the failure of the pressure probes used to measure water levels

reestablishing hydrological data collection within the Kubango catchment[7]. At OKACOM's request, the Project responded by reviewing readily available water resources information and proposing a phased program for reestablishing hydrologic monitoring on the Kubango and Kuito rivers[8]. The report, outlining the requirement for a more detailed information review and a field reconnaissance leading to recommendations and action, provided the framework for subsequent actions undertaken jointly by the EPSMO and the USAID/OKACOM Project. A joint field reconnaissance was completed in April 2005[9] with agreed upon recommendations for a phased reestablishment of monitoring. The framework outlined the need for formal and on-the-job training, but without specificity. This report establishes how data are collected and by who and makes specific training recommendations.

2.3 OKAVANGO DELTA MANAGEMENT PLAN PROJECT

The Okavango Delta Management Project was designed to integrate resource management for the Okavango Delta in a way that ensures resource conservation to provide benefits for present as well as future generations though sustainable use of its resources. The project began in 2003 and is currently scheduled for completion in July 2006. The project is comprised of 12 components leading to an integrated management plan for the Delta. The objective of the Hydrology and Water Resources Component (component 4) is to develop a hydrologic model for the Delta and includes an activity to establish an improved hydrological and climatic monitoring program for the Delta. A hydrologic cycle model has been developed with initial environmental change and development scenarios run. However, the model depends on reliable data and will be more robust and more accurate as better data are collected and made available. The Okavango Delta Management Plan project has evaluated data collection, processing and archiving as part of developing recommendations for improved hydrologic monitoring and has concluded that a complete overhaul of the data collection procedures should be undertaken. In addition, recommendations for some 27 additional surface water gauging stations and a like number of groundwater stations has been made along with procurement recommendations for digital data logging equipment. The equipment has not yet been purchased and improved data handling procedures have not yet been developed and implemented. This component of the project does have a training element. The USAID/OKACOM Project should coordinate all training activities in Botswana with the Okavango Delta Management Plan project.

[7] The upper Angolan part of the basin including the Kubango and Kuito River Basins. The terminology is used because it defines one of the 77 defined catchments in Angola.

[8] Crear, Steve, Rehabilitation and Upgrading of Hydrometric Network for the Upper Okavango River Basin, Draft Proposal / Terms of Reference, UNDP-GEF, Environmental Protection and Sustainable Management of the Okavango River Basin Project, January 3, 2005

[9] Crear, Steve and Alan Simmons, Initial Field Reconnaissance Report: Rapid Assessment of the Hydromet System, USAID/GEF and OKACOM, June 2005

3. MONITORING PROGRAMS IN ANGOLA

Angola has relatively complete hydrologic record for the Kubango River basin from the middle to late 1950s until independence and the subsequent war starting in 1974-75. Detailed analysis has recently been completed for a ten year period (1963-1973) for thirteen stations in the basin. From 1974 to today, the hydrometric network throughout the country has fallen into disuse and disrepair. Today, the Departamento Recoursos Hídricos (DRH) of the Direcçao Nacional de Águas (DNA) is working to reestablish hydrometric monitoring for select stations using modern electronic data logging instruments.

3.1 INSTITUTIONAL SETTING

The Direcçao Nacional de Águas (DNA) within the Ministério de Energie e Águas is currently responsible for water resources management in Angola. DNA has three departments, one of which, Departamento Recoursos Hídricos (DRH) has direct responsibility for water resources monitoring and data collection at gauging stations around the country. The other two departments are Departamento do Abastectmentoto Águas e Saneamento responsible for water and sanitation and Departamento de Licenciamento e Fiscalização, responsible for water quality monitoring, permits, and licensing. Total staffing for DNA is about fifty. The Ministério de Energie e Águas also has oversight responsibility for Gabinete para Administração da Hidrografia da Bacia do Rio Kunene (GABHIC) and Gabinete de Aproveitamento do Médio Kwanza (GAMEK), which are responsible for managing water resources in the Kunene catchment and hydropower development in the middle Kuanza River. The Departamento Recoursos Hídricos is staffed by seven dedicated hydrometric Technicians and one Technician with provincial administration duties as well. Six of the Hydrometric Technicians are young with limited experience. The Department also includes a geographer/GIS specialist and an economist. The recently completed Norwegian-financed National Water Sector Management Project assisted in evaluation and publication of selected historical hydrologic data sets[10] (including upgrading computer and software systems), provided water monitoring equipment that gave the Department experience with modern electronic data collection methods, prepared a rapid assessment of the nation's water resources, and sponsored hydrometric training for Technicians.

The water sector is currently in a transition driven by the Law on Waters (Law no. 06/02) and the Ministério de Energie e Águas' Strategy for Development of the Water Sector[11], and by a national program to decentralize responsibility to Provincial Administrations. The water sector strategy outlines significant institutional changes including establishment of a Conselho Nacional de Águas and Regional Conselho Regionais de Águas (National and regional Water Councils) to advise and coordinate sector activities and development; an Órgão de Tutela (Water Management Department) to manage water use including registration, granting licenses, and setting water resource use fees; an Instituto dos Recursos Hídricos (Institute of Hydrologic Resources) to maintain sector inventories and promote sector research and technical development; an Administrações de Bacias (Basin Administrations) to plan and implement programs and projects, and a Fundo Nacional de Recursos Hídricos (National Hydrological Resources Fund) to receive water use fees and other funds and finance scientific and development studies. It appears that conceptually, the functions of the Department of Water Resources will fall under the Institute of Hydrological Resource with activities at least partly financed by the National Hydrological Resources Fund. However, to date neither the institute nor the fund has been formally established.

At the same time that these changes are in progress within the water sector, Provincial Administrations are taking on more responsibilities in all sectors. Provincial Administrations are creating Provincial Directorates of Energy and Water with Water Departments that will increasingly responsibility for water sector activities. These Departments have limited staff, many with only basic qualifications. Efforts are underway to create public companies to manage water supply and sanitation in Provincial capitals but water and sanitation services for municipal towns will be the responsibility of these Provincial water departments. It is not clear yet whether Provincial water departments will eventually take over responsibility for hydrometric monitoring or if the yet to be formed basin administrations will have responsibility. The USAID/OKACOM Project should work with the DNA, the Kuando Kubango Provinical Administration, and the Regional Water Council (if created) to assist in clarifying institutional roles and monitoring responsibilities.

[10] Including datasets for 13 stations in the Kubango catchment

[11] Programma de Desenvolvimento do Sector das Águas, Ministério de Energie e Águas, Luanda, Janeiro de 2004

Groundwater resources have been the responsibility of the Instituto Nacional Geoligie de Angola within the Ministry of Geology and Mines. Apparently, the institute has a group responsible for groundwater resources. This responsibility is supposed to be transferred to the Departamento Recoursos Hídricos, but apparently without databases and whatever digital data that might be available because this groundwater information is part of the larger Institute Nacional Geoligie database. Limited information exists about groundwater resources in the Kubango catchment and no comprehensive surveys have been completed, although some historical information is available at scattered locations including the Instituto Nacional Geoligie, the Direcçao Nacional de Águas, the provinces, and various consulting companies. It would take time to assemble anything of significant value.

The Instituto Nacional de Meteorologia e Geofísica holds the nation's climate data. They had an extensive network of reporting stations in the past with 8-12 stations in the Kubango catchment. All were abandoned and fell into disrepair during the last 30 years because of the war. Historical information was published in annual summaries and some of this information is now partly digitized (although it is not clear that any of the digitized data are for stations in the Kubango catchment). The Instituto Nacional de Meteorologia e Geofísica is in the process of reestablishing stations and now have just (as of November, 2005) established a station in Menongue. These stations are manned and collect information which is radioed to Instituto Nacional de Meteorologia e Geofísica offices in Luanda on a regular basis. The Instituto Nacional de Meteorologia e Geofísica is involved in a national program with the Ministério da Agricultura e do Desenvolvimento Rural to establish a network of rainfall stations using volunteers at schools and government offices and facilities throughout the country.

3.2 INSTRUMENTATION AND DATA COLLECTION PROCEDURES

Angola's Departamento Recoursos Hídricos, with the assistance of the NORAD-financed National Water Sector Management Project, has made a commitment to re-establish hydrological monitoring using digital methods. This is a logical decision given that almost all stations need repair and upgrading, old equipment is gone, and a new cadre of Technicians is now being recruited and trained.

Instrumentation

Angola has been able to reestablish monitoring at only eleven stations, none in the Kubango catchment. All stations are equipped with data logging instruments including the HYCOS DCPs, OTT Thalimedes data logger and one OTT pressure probe[12]. Angola also has OTT C-31 current meters and an Acoustic Doppler Current Profiler (ADCP) for gauging, rating and determining discharge. Some fifteen more OTT Thalimedes are ready for installation in the Kunene and Katubela catchments and other locations in the north. None are scheduled for installation in the upper Okavango basin.

The USAID/OKACOM Project is planning to provide instrumentation for five stations in the upper Okavango basin. This follows the reconnaissance of April 2005[13] and subsequent meetings with responsible hydrologists from the three riparian countries. De-mining operations and current road conditions in Kuando Kubango Province impacts the choice of stations for first phase installation, but a second phase is planned once initial installations are completed satisfactorily. As of November 2005, the stations scheduled for inclusion in the Phase I program include:

- Menongue on the Luahaca tributary of the Kuebe River
- Menongue on the Kuebe River above the confluence with the Luahaca River
- Kubango on the Kubango above the confluence with the Kutato River
- Kuchi on the Kuchi River below the confluence with the Kacuchi River
- Kutato on the Kutato River, a tributary of the Kubango River.

As the road from Menongue to Kuito Kanavale has recently reopened, the Kuito Kanavale site will be evaluated prior to installing equipment. The Kuito Kanavale site will be substituted for Kutato if possible so that at least one

12 For a listing of these stations and digital equipment in use, see Appendix 8.

13 Crear, Steve and Alan Simmons, Initial Field Reconnaissance Report: Rapid Assessment of the Hydromet System, USAID and OKACOM, June 2005

station on the Kuito is reestablished during the Phase I program. All stations will be equipped with OTT Thalimedes data loggers, but no telemetry has been included due to concern about vandalism and operation and maintenance issues. The recommendations of the May meeting[14] should still guide the instrumentation program for the upper Okavango basin to the degree that logistics allow and Angolan priorities are first considered.

Data Collection and processing procedures

The use of digital equipment in Angola simplifies the data collection process considerably in that processing analog recorder charts and creating a digital record is administratively complicated and prone to error (chart interpretation and number transposition, for example). However, the lack of chart backup means that data lost because of equipment or logistical problems cannot be edited or interpreted and is lost.

The OTT equipment (Thalimedes and LogoSens data loggers) are downloaded in the field using the OTT Vota2 multi-functional processor which allows a first visual look at the data while still in the field. It does not appear that the Department is currently using log books or regular site visit report sheets to document field activities. Information collected on the Vota2 is downloaded into the OTT Hydras3 software. This data are then exported in a text format and reformatted with a special routine for importation into HYDATA 4.2, the software used for digital data storage and archiving.

Conceptually, the data collection process for the HYCOS DCPs is to download data from the Pilot Regional Center's website following telemetric transmission and processing. However, this has not proved a workable method. Inspection trips to the field from Luanda or the several field offices in the south provide the opportunity to replace data modules so that data can be downloaded in the office. Until these data are downloaded and evaluated, it is not possible to tell how good the data sets are. Problems with the pressure sensors at Angolan stations and elsewhere have caused data loss.

Although senior Technicians know how to use the OTT C-31 current meters that the Department has for gauging operations, the recent provision of an Acoustic Doppler Current Profiler (ADCP)[15] has the potential to revolutionize the current gauging process. No stream gauging and discharge measurements have been made with the C-31 current meters in many years and the Department is committed to eventually using ADCP technology for current gauging at critical locations and to check traditional gauging at other locations (velocity meters will be used at some locations for the foreseeable future). Although the Department has an ADCP, they have not yet completed current gauging for the eleven reestablished stations.

The above description may suggest that data are being collected on a regular basis, but this is not in fact so. Severe budgetary constraints since the end of the National Water Sector Management Project has limited field visits and normal maintenance and data collection has not been possible, even for the eleven existing stations. Sites visited close to Luanda during field visits[16] did not appear to have been visited for more than four months, batteries in use were not long lasting alkaline, and site maintenance did not appear to have been completed recently. Procurement and budgetary decisions appear to be made at the Ministerial level, severely constraining the day to day operations of the Department.

3.3 STAFFING AND TRAINING

As indicated above, the technical capacity of the Departamento Recoursos Hídricos is severely limited. Current staffing for hydrologic monitoring for the entire country consists of eight Technicians, most young and inexperienced. Only two members of the Department's technical staff predate Angolan independence when hydrological monitoring effectively ended. The Norwegian-financed National Water Sector Management Project provided assistance with English language training for some staff, funded training in the use of HYDATA software, and provided considerable on-the-job training through the project's resident Senior Engineer. Several staff were also provided limited training through the HYCOS Phase I program, both in the field for HYCOS DCP installation,

14 OBSC, Summary of Discussion, key decisions and issues, and Actions to be Taken, Meeting to Discuss Water Resource Monitoring on the Okavango River, May 16, 2005

15 Procured by the National Water Sector Management Project

16 See Appendix 2

set-up and operations; and in Pretoria for HYDATA use and data processing. The training that Technicians receive is ad hoc, rather than part of a formalized skills development and career advancement program.

3.4 FINDINGS

The major constraints to hydrologic monitoring are lack of staff and lack of budget. The hydrometric staff is but eight Technicians for a country with 77 defined catchments (with Kubango/Kuito River system as one of them). Monitoring is taking place now in only nine of these catchments. No monitoring is taking place in the Kubango catchment.

The Director of the Departamento Recoursos Hídricos, Mr. Paulo Emilio de Mendez, is the only member of the staff that has any formal hydrological training. Two chief Technicians have worked with the department a long time and have lots of relevant experience. The Director is experienced and knowledgeable, but further human resources are needed to fulfill all the hydrological work required of the Department.

Historical data for the Kubango catchment do exist. Digitizing and analysis for a ten year period (1963/4-1973/4) was completed for thirteen stations along the Kubango and Kuito Rivers and their tributaries. Additional data going back to the mid-fifties is available in annual yearbooks.

Reestablishing a hydrological monitoring network with modern equipment is taking place very slowly as resources become available. If USAID/OKACOM believes that it is important to reestablish monitoring in the Kubango catchment, then it must be prepared to cover most of not all of the costs for equipment, transportation, allowances, training, and possibly staff as well.

3.5 TRAINING NEEDS

Training needs for hydrological monitoring are many and varied. Part of the program should be the design of a modular training program to replace the ad hoc training that takes place now. The overall program should include, but not be limited to:

- Basic hydrological principles
- Methodological training for Technicians
- Use of digital hydrometric instrumentation
- Gauging techniques and use of the OTT C-31 current meter
- Care and use of the ADCP current profiler
- Project planning, budgeting and management, and
- Computer training.

However, before such training can be carried out effectively, the Department should engage additional staff.

For the purposes of reestablishing monitoring in the Kubango catchment, training should focus in basic skills development for the yet to be hired Technicians (tentatively identified as Firmino da Conceição Jordão and Teresa Maiamba Tchanja Paulo) who will be stationed in Menongue. Their training should include:

- Methodological Training in Luanda
- Field Training in Kunene Province
- Computer Skills Training
- Field Installation, and Initial Discharge Measurement Training
- Follow-up Training and Support

This training can be provided by the current staff of the Department if logistical support can be provided. Details for this training is provided in Appendix 4.

In spite of the lack of a formalized training program, the Department staff would benefit from additional specific training. This includes:

- Additional training in the installation and set up for Thalimedes data loggers,
- Gauging techniques and use of the OTT C-31 current meter,
- Care and use of the ADCP current profiler (apparently to be covered as a last contribution of the NAWASMA Project),
- Development and training in the use of data collection forms and procedures
- English language training.

4. MONITORING PROGRAMS IN BOTSWANA

Botswana has been monitoring water resources in the Okavango Delta for 72 years when the first discharge measurements were made at Mohembo, along the Namibian border in 1933. Since then Department of Water Affairs has established a number of flow and water level monitoring stations in the Delta, some permanent with relatively long records and some with records of only a few years. Hydrologic monitoring equipment and procedures still depend on visual observation of stage with analog chart recordings at some sites. At Mohembo, river gauging and discharge measurements are made daily. Within the Delta, the hydrology is complex and still not well understood with evapo-transpiration and infiltration important factors that have yet to be well characterized. Flow rates in the lower Delta are much lower and discharge measurements more difficult to make and understand.

4.1 INSTITUTIONAL SETTING

The Ministry of Minerals, Energy and Water Affairs is the parent Ministry for the Department of Water Affairs. The Department of Water Affairs is divided into six major operational Divisions including Design, Construction, Operation and Maintenance, Electrical and Mechanical, Groundwater, and Hydrology and Water Resources. The Hydrology Division, in addition to its role in supporting the Department's mission to assess, plan, develop and maintain water resources for domestic, agricultural, commercial, industrial and other uses, is responsible for surface water monitoring throughout Botswana. The Hydrology Division has four sections (Hydrology, Water Resources Planning, Aquatic Vegetation Control, and Water Law) and is staffed by some nine professionals and twelve technical staff. Mr. Kalaote Kalaote, one of the Division's three Principle Water Engineers, is currently a member of the Okavango Basin Steering Committee (OBSC). He has responsibility for planning and is the Project's point of contact for hydrologic monitoring although Mr. Tapson Bombo, the Supervising Technical Officer for the Division is in charge of managing the hydrologic monitoring program nation-wide. The Hydrology Division fulfils its responsibility for monitoring through hydrology sections located at a number of Department of Water Affairs Regional Offices[17]. Hydrology Sections have been established within the Regional Offices in the Okavango basin at Maun and Gumare. Station Managers, who may be drawn from any of Department of Water Affairs' Divisions, have overall administrative and budgetary responsibility for activities within their Regions. Although Hydrology Sections are administered by Station Managers, they take technical direction from the Headquarters Hydrology Division. Hydrology Sections are managed by an Officer-in-Charge, who directs the day to day activities of Hydrology Section staff. Annual budgets for water resource monitoring are developed by Hydrology Sections and reviewed and amended by the Hydrology Division prior to submission to Station Managers for inclusion on Regional Office budgets. Station Managers have responsibility for budgets and have the authority to realign them as specific circumstances within his region dictate.

Other Government Departments also collect information of hydrologic relevance and importance. The Department of Meteorological Services maintain manned stations at Maun and Shakawe. These stations, and some 15 others that collect rainfall and other information on a more sporadic basis, are managed by the Climatology Division of the Department. Information from these secondary locations, manned by volunteers and staff of other government departments, is radioed to the Department in Gaborone.

The Department of Water Affairs' Groundwater Division monitors groundwater levels in and around well fields along the western margins of the Delta and in the downstream tributaries of the Delta's tributaries. Long term groundwater monitoring is also the responsibility of the Department of Geological Survey. The Department's Hydrology Division monitors water levels in ten areas around the country. In the Okavango basin, they are now planning to establish a monitoring program in a geological exploratory area which is generally between the Okavango Delta and the Namibia border to the west. The hydrogeology monitoring unit is staffed by less than ten technical officers, all stationed at the Department's offices in Lobatse.

[17] Botswana is a dry country. Hydrology sections are only established and maintained in those offices which have jurisdiction over areas where perennial streams exist and water levels and flow information is collected.

4.2 INSTRUMENTATION AND DATA COLLECTION PROCEDURES

Although the Department of Meteorological Services and the Department of Geological Survey do operate and maintain instrumentation for collection of meteorological and hydrological data[18], this section focuses specifically on the instrumentation and data collection processes used by the Department of Water Affairs to collect hydrological data within the Okavango basin.

Instrumentation

The Department of Water Affairs maintains both water flow and water level measuring stations. Within the Okavango region, including the Delta stem reaching the Namibia border, there are some 65-70 gauging stations. Of these some 12-15 are equipped with chart recorders, mostly older Stevens recorders, but with some OTT equipment as well. Much of the equipment is considered in poor condition. A complete listing of stations, including locations, data collection frequency, period of record, and other information is now being prepared by Okavango Delta Management Plan Project. Most stations are water level stations with gauge plates (staff gauges) installed and no recording instruments. Discharge measurements are made daily at Mohembo and at about 30 other stations on a less frequent basis. All discharge measurements are made using current meters such as the OTT C-31. An electronic cableway system has been installed at Mohembo, but it is not yet in operation due to problems during installation. Botswana made early attempts to collect data digitally, with a joint MET services/DWA program during the mid-1990s to install about eight stations that recorded water level, rainfall, and several other meteorological parameters with satellite transmission of data to Gaborone. The systems never worked properly, the company was sold, and the systems abandoned (the remains on one of these systems can still be seen at the Mohembo camp). Botswana also participated in the HYCOS program and installed five stations, one located at Mohembo with the remaining stations located outside the Okavango area. Recently, the United States Geological Service also assisted the Department of Water Affairs by providing telemetric hydrological data collection stations which are located in the Limpopo River basin. These also have been problematic and are not yet operating as designed. The Department of Water Affairs' experience with digital instrumentation has not been good so far. Additional problems with these and other gauging stations are that within the Okavango Delta proper they are hard to access. Also vandalism and damage by wild animals has deterred commitment to expensive telemetry systems that require photovoltaic panels and antenna that must be properly aimed. Senior Hydrology and Water Resources Division staff understand the potential for modern digital data collection, but are cautious about making commitments, given experience to date. The Okavango Delta Management Plan has plans to improve the hydrologic instrumentation network by procuring and installing 27 digital surface water level recorders that can be downloaded with a suitable Personal Digital Assistant (PDA)[19] and a similar number of groundwater recorders. The Department of Water Affairs is moving inexorably toward modern data collection methods.

Data Collection Procedures

Data are collected in the Okavango River basin by staff stationed at the Department of Water Affairs' Maun and Gumare Regional Offices. A permanent camp has been established at Mohembo as an outstation of the Gumare Regional Office. At Mohembo, daily gauging takes place, about a two hour operation. In principle, Technicians lead teams into the field to collect level data, change chart paper and service recorders, and take discharge measurements on at least a monthly basis. In practice, Technical Assistants (Artisans in the nomenclature of DWA) lead many if not most of these teams and station visits for many stations are not made with regularity. At level stations, water levels are read, gauge plates adjusted to local benchmarks. Where chart recorders are installed, charts are changed, and recorders serviced (clocks wound, ink pens replaced, etc.). Gauge plate levels are entered onto station books brought into the field for this purpose while charts are brought to Regional Offices for processing. Daily readings are taken from charts at the Regional Office and entered onto forms that

[18] Met Services operate climate stations at Maun, Shakawe and Xakanaxa. Geological survey has plans to monitor water levels in 8-10 boreholes west of the Delta.

[19] Instrumentation of Hydrologic Network, Okavango Delta Management Plan Project/Hydrology and Water Resources Component 4, (Draft) October 2005

are forwarded annually to the Department of Water Affairs' Hydrology and Water Resources Division in Gaborone.

Discharge measurements are carried out using OTT C-31 velocity meters. Velocities are measured at several depths and horizontal locations with mean velocities and discharge calculated using internationally accepted methods. Measurement teams may be led by Technicians or Artisans. Discharge calculations are made either in the field or at the Regional Office using calculators. Discharge figures, along with mean velocities, cross sectional areas and water levels are forwarded to the Department of Water Affairs' Hydrology and Water Resources Division annually as described above.

Technicians in Gaborone review data prior to directing a data entry clerk to enter the data into the HYDATA database. Data in the database can be edited and corrected at any time that anomalies or errors are detected by data users. Changes must be discussed with the Technical Officer responsible for the database

For six stations[20] in the Okavango Delta (along with information for other important stations in the country), information is sent weekly by e-mail or phone to the Hydrology Division offices in Gaborone. This data are reviewed and entered into electronic forms for the informational needs of the Department of Water Affairs' Senior Management. It is not clear that the HYDATA database is used on a regular basis except for special studies conducted by Division hydrologists or consultants.

All of the above process is in the hands of the Department of Water Affairs' Technical staff. It is not clear how data interpolation is completed, what specific data checking and verification procedures are followed in Gaborone prior to data entry into the HYDATA database, or what procedures are used when errors are spotted by Technicians responsible or by hydrologists who may be using the data. The Okavango Delta Management Project recommends a "complete overhaul of the routines in water level readings and discharge measurements to rationalize field work and secure data reliability"[21].

4.3 STAFFING AND TRAINING

Although hydrological data are used by professionals within the Hydrology Division, their consultants, and others, data collection and management is left largely in the hands of technical officers and industrial class employees, both in Gaborone and at regional offices. Five Technical Officers and seven Technical Assistants work in Gaborone, not all on hydrologic information from the Okavango basin. About twenty staff, including technical officers, Technical Assistants (Artisans), and Gauging Assistants (Industrial class) work in each of the Hydrology sections in Maun and Gumare. The Mohembo camp is operated under the direction of a Technical Officer and has a full complement of ten including a driver, boat operator, and watchmen.

A Diploma (normally a three year program of post secondary study) is required for Technical Officers. Normally, the Officer in Charge of the Hydrology Section in a regional Office is a Senior Technical Officer. The Technical Staff is managed by a Superintendent/Chief Technical Officer. Entry level requirements for Artisans is the Botswana General Certificate of Secondary Education which is the general equivalent of Cambridge O-level. But the requirement is often relaxed in order to fill vacant positions. Staff can advance from gauging assistant to Technical Assistant through experience and training.

The Department of Water Affairs maintains a Training Section which is responsible for staff development. The Section managed three types of training programs-training courses taught by the Section's Training Officers, training courses taught by specialists from within DWA, and training courses offered by outside institutions such as the Botswana National Productivity Centre, The College of Business and Information Technology, or the University of Botswana.

[20] In the Okavango Delta, the stations are : Mohembo, Azkue, Maun Bridge, Boro Junction, Mogapelwa, and Toteng

[21] Recommendations for Improved Hydrologic Monitoring, Okavango Delta Management Plan Project/Hydrology and Water Resources Component 4, May 2004

All training provided for Gauging Assistants and Technical Assistants is organized by the Training Section with courses designed and taught largely by Technical Officers. In October 2005, a six week course for Gauging Assistants was conducted and a three month course for Technical Assistants was taught two years ago. The recent gauging assistants course included modules on basic math and algebra, basic statistics, surveying and plotting cross sections, map reading, basic hydrology, care of instruments and chart reading, and introduction to water law and aquatic vegetation. These courses are approved and satisfactory completion can lead to promotion and salary increases.

4.4 FINDINGS

Of the three riparian countries, Botswana has, by far, the largest number of gauging stations. This is not surprising as the whole of the Okavango Delta with its complex hydrology lies within its borders. Botswana also has a significantly larger cadre of Technicians and Technical Assistants assigned to hydrologic data collection with approximately forty people posted to the Department of Water Affairs' Regional Offices in Maun and Gumare.

The Technical Staff, led by the Supervising, Chief Technical Officer, is in charge of data collection and processing with hydrologists reviewing the data only when they need the data for projects that they are involved in. Primary data can be modified at any time if hydrologists or other data users find problems or errors.

Although the Department of Water Affairs' training program is well defined, field staff, especially Artisans, do not fully understand what the data they collect is used for and why accuracy is important. They have not been exposed to the modeling work being completed by the Okavango Delta Management Project and how important reliable data are to the modeling effort.

4.5 TRAINING NEEDS

DWA has a formal training program for Technicians and Technical Assistants (Artisans). Most important is that these programs be offered on a regular basis and that refresher courses focus on data collection issues that arise. Beyond this basic training, four specific training needs have been identified. These are:

- Awareness of the importance of hydrologic data for Artisans and Gauging Assistants,
- Installation, use and maintenance of digital hydrologic monitoring equipment,
- Maintenance and repair of chart recorders,
- Data evaluation, verification, processing, and editing (elements of the overhaul of routines as recommended by the Okavango Delta Management Plan).

As training is also a feature of the Okavango Delta Management Project's Hydrology and Water Resources Component 4, any training considered by the USAID/OKACOM Project should be coordinated with Okavango Delta Management Plan staff and consultants.

5. MONITORING PROGRAMS IN NAMIBIA

Namibia's perennial rivers are all border rivers with the Kavango River in the north-east as one of the most important. The Department of Water Affairs and Forestry with responsibility for sector planning has established important gauging stations at Rundu and Mukwe, before and after the confluence of the Kavango and Kuito Rivers (which enters the Kavango from Angola at Dirico, Angola. These two stations, both with relatively long records (Rundu since 1945 and Mukwe since 1949) along with the station at Mohembo, Botswana provide the best information available for characterizing flows into the Okavango Delta and the gross contributions from the Kubango and Kuito Rivers in Angola.

5.1 INSTITUTIONAL SETTING

Namibia has recently promulgated a new water law which "provides for the management, development, protection, conservation, and use of water resources; and establishes a Water Advisory Council, a Water Resources Management Agency, a Water Regulatory Board, and a Water Tribunal"[22]. The Act, which is not yet in force, pending announcement by the Minister, establishes principles of basin management through basin management committees. One of the functions of basin management committees is "to collect, manage and share such data as are necessary to properly manage the basin in coordination with the Water Resources Management Agency"[23]. One of the functions of the Water Resources Management Agency is "the collection, analysis, and sharing of data concerning the conservation and management of the water resources of Namibia"[24]. As this law is not yet in force, the Ministry of Agriculture, Water and Forestry has principle responsibility for hydrologic data collection. However, when the Law becomes effective, there may be some change to the institutional setting described in the following paragraphs.

The Ministry of Agriculture, Water and Forestry is the parent Ministry for the Department of Water Affairs and Forestry (DWAF). DWAF is divided into three Directorates, namely Rural Water Supply, Resource Management, and Forestry. Directorate of Resource Management is made up of five divisions: Geohydrology, Environment, Law Administration, Strategic Planning, and Hydrology. The Hydrology Division, with 41 approved posts, is now staffed by three managers, ten professionals (Hydrologists/Technicians with Degrees/Diplomas) and twenty Technical Assistants and other non-professional staff in four sub-divisions. Mr. Guido Van Langenhove is currently the Deputy Director in charge of the Division. He develops and manages budgets for the hydrologic monitoring program. The Hydrological Support Services Sub-Division is responsible for all hydrological data collection. The full staff complement is twenty-six, but a number of positions are currently vacant. The Surface Water Database Sub-Division, with a current staff of six, is responsible for managing final hydrologic data verification, digitizing charts, and entering data into their Hydstra database. Other Sub-Divisions include Hydrological Investigations and Water Resources Management. All staff are stationed in DWAF's headquarters in Windhoek. The Hydrologic Support Services Sub-Division is responsible for hydrologic monitoring at some 105 stations nation-wide. All but those on the perennial rivers (Kavango, Kunene, Kuando, Zambezi, and Orange) and those located at dams are on ephemeral rivers that are dry most of the year. Support services staff are all located in Windhoek and all station visits to the Okavango gauging stations at Rundu and Mukwe require a drive of some 700 km.

The Directorate of Resource Management is also responsible for groundwater resources through the Geohydrology Division, which houses a borehole database (which is about ten years backlogged) and water use permitting through the Law Administration Division. The Planning Division is responsible for national water resource planning based on national policies and priorities.

In the past, The Department had responsibility for managing bulk water supply for Windhoek and other major towns and some other major consumers such as mines and irrigation schemes. In 1997, this responsibility was devolved to a new entity, the Namibia Water Corporation Ltd, commonly referred to as NamWater. NamWater manages and operates the main water supply systems in the country, including aquifers, major dams, and the Eastern National Water Carrier[25] that provides bulk water to central Namibia and Windhoek. NamWater

[22] Water Resources Management Act (Act No. 24 of 2004), Government Gazette of the Republic of Namibia, 23 December 2004.

[23] Ibid

[24] Ibid

[25] See Appendix 3 for some detail about NamWater's bulk water system for the central area of the country

monitors water levels in their dams (and the Grootfontein-Omatako Canal) and shares this information with DWAF's Hydrology Division. Some duplication in data collection remains, but the purposes for collecting the data are slightly different with NamWater interested in reservoir management and the Hydrology Division interested in monitoring the national water resource. This duplication appears acceptable for the moment as final details on the division or responsibility are ironed out.

The Department of Meteorological Services, in the Ministry of Transport and Communication, has maintained a manned climatic station Rundu and collected rainfall data at about 10 stations along the Kavango River for many years. The digital rainfall record is now about ten years with some stations reporting for about 50 years. MET Services is in the process of upgrading stations with digital equipment at manned stations and installing 25 unmanned stations around the country. Six of these stations will be in the Okavango River basin[26] and should be of interest.

5.2 INSTRUMENTATION AND DATA COLLECTION PROCEDURES

Although the Department of Meteorological Services and NamWater operate and maintain instrumentation for collection meteorological and hydrological data[27], this section focuses specifically on the instrumentation and data collection processes used by the Hydrology Division to collect hydrological data within the Okavango basin.

Instrumentation

The Hydrology Division currently operate and maintain three gauging stations in the Okavango River basin – two at Rundu[28] and one at Mukwe. Two cableways for measuring discharge had been installed-one at Rundu and one at Divundu. The Rundu cableway was destroyed during the war before Angolan independence. The Divundu cableway has been out of service for several years due to mechanical breakdown. Instrumentation at the gauging stations is as follows:

- Rundu (Namwater pump station):Gauge plate, Alpina chart recorder (OTT compatible), OTT Thalimedes data logger
- Rundu (HYCOS): Gauge plate, HYCOS Enhanced Data Collection Platform including sensors for water level, water temperature, turbidity, conductivity, solar radiation, wind speed and wind direction, air temperature and relative humidity.
- Mukwe: Gauge plate, Alpina chart recorder, OTT Orphimedes data logger

Note the duplication of data collection at the Rundu (Namwater pump station) and Mukwe, with both digital and analog recording devices installed. At most locations on both the perennial and ephemeral rivers, OTT type chart recorders are the principle method for data collection. The Division has only recently purchased and installed the OTT Thalimedes data loggers, an Orphimedes data logger, and two pressure sensors coupled to OTT LogoSens data loggers[29]. There are less than ten digital water level data loggers in the country now, but indications are that this is the future for data collection if digital systems prove reliable and as spare parts for older chart recorders become harder to find. Currently the OTT data loggers are being operated in parallel to OTT and Alpina chart recorders as a test of their performance.

Data Collection Procedures

All Technicians, Technical Assistants and other staff responsible for hydrologic data collection are stationed in Windhoek. The Department's goal is to visit each station at least every three months by sending teams out on circuits to stations around the country. During the rainy season, visits may be more often as other Hydrology Division staff visit the field to observe conditions and collect information. Field Teams should be led by a

[26] Kahenge, Rundu, Bagani, Tsumkwe, Kavango-A and Kavango-B,

[27] Note that NamWater has installed radar based water level recording instruments along the Grootfontein-Omatako Canal and that their experiences may have value to IRBM Project participants at some point.

[28] One Rundu station is a longstanding station at the NamWater pump station, the other is a HYCOS station about two kilometers downstream.

[29] The LogoSens/pressure sensor systems are currently in use on the Kunene and Fish Rivers.

Technician or Hydrologist (with staff attrition, Chief Technical Assistants often lead field teams) with Technical Assistants and work hands to perform much of the detail work of inspecting the site, replacing charts, winding clocks, and replacing batteries. The team leader is responsible for entries into log books kept at each site to record arrival time, current status of the site and its equipment, work performed during the visit, and what work remains to be completed. Specialized log sheets have been developed for the HYCOS station and the OTT data loggers. Unlike in Angola, where OTT Vota2 is used to down load data in the field, in Namibia, a laptop computer is used for the purpose. When discharge measurements are made (which is rare because most sites are on ephemeral rivers[30]), measurements are made on a worksheet designed for the purpose. Actual calculation of discharge is usually made following return to the office.

Data, largely in the form of chart recordings, is first reviewed in the office by Technical Assistants who make basic notes and alterations on the charts. The charts are then checked and further corrections made as necessary by the Hydrologists/Technicians who have regional responsibility for gauging stations and reviewing and understanding hydrologic data and understanding regional hydrology. The resulting information is digitized and entered into data files by Technical Assistants working in the Surface Water Database Subdivision. The Chief Hydrologist will then take a final look at the data, checking for anomalies and consistency, before sending back to the regional Hydrologist/Technician for final acceptance. If any concerns are raised by the Chief Hydrologist, then an iterative process is initiated that resolves them prior to archiving. Once accepted, the data are archived in the Hydstra database. The goal is to have this data finalized within six months but this target is not always reached.

5.3 STAFFING AND TRAINING

All members of the Hydrology Division are in some way involved in hydrological data collection, either in collecting primary data, checking and verifying data, archiving data, and using the data for hydrological investigations. The Department is currently staffed by nine Hydrologists including the head of the division, four Diploma-level Technicians, and seven Technical Assistants. Current minimum qualifications for Technical Assistants is "Grade 10", which is two years below the International General Certificate of Secondary Education, which is the senior secondary school qualification.

The Hydrology Division recognizes that both professional and non-professional staff need additional training in hydrology and hydrologic monitoring. Undergraduate degree programs do not normally offer a hydrology specialization and Diploma courses only touch on the hydrologic cycle. The Department does not have a training center, but does make arrangements to use the NamWater training center on occasion. The Division does not find that formal in-house hydrologic and hydrometric training courses for hydrologic analysis are warranted because the number of entering staff is small. The Division did develop a Hydrology Training Manual: The Hydrology of Small Farm Dams but has not offered the course in several years now. Training courses offered by DWAF/South Africa have been considered in the past but not found to be applicable because of the geographical and hydrologic differences between South Africa and Namibia.

Entering Technicians and Technical Assistants receive about two weeks of training focusing on basic hydrology (2-3 days), operation and maintenance of recording instruments (2-3 days), and data evaluation and editing (5 days). This training is offered to new employees or as a refresher in most years. Otherwise, training is largely on-the-job with more experienced staff providing guidance and oversight of field operations. Short workshops occasionally supplement field training as necessary. Formal training offered to date on the installation and use of digital equipment has been limited to one day on the theory and installation and use of the OTT Thalimedes and a similar level of training for water level probes. A few staff were also provided limited training through the HYCOS Phase I program both in the field for HYCOS DCP installation, set-up and operations.

5.4 FINDINGS

Dependence on surface water for water supplies for the central area of Namibia including Windhoek has forced Namibia to focus on planning and hydrological monitoring. Consideration of such projects as the extension of the Grootfontein-Omatako Canal to Rundu and the Popa Falls hydroelectric scheme (even though both projects are

[30] The last rating at Rundu (NamWater Pup station) was 1976, the last at Divundu was 2003, and the HYCOS site has never been rated.

currently shelved) entails careful planning which requires accurate hydrologic data. To date, neither Angola nor Botswana have proposed any major surface water development projects for the Okavango River basin.

Although Namibia is monitoring water levels and flows at 105 sites throughout the country (many dry most of the year), only 3 gauging stations are located on the Kavango River. Current gauging at Rundu has not been completed for more than 25 years and so old rating curves are used to estimate flow. Even so, data have from these sites is considered among the best available in the Okavango basin due partly to stable sections that capture all flood flows.

Collection, verification, and archiving appears to be rigorous, with concerted efforts to ensure data accuracy and reliability. Formalized procedures are in place and appear to be followed for the most part. The process of checking and rechecking data before final entry into the hydrologic database is more thorough than elsewhere in the basin.

Constraints imposed by geography and logistics make data collection expensive and limits the time that Hydrologists, Technicians, and Technical Assistants can spend at gauging stations. Long drives only every three months to gauging stations in the basin means that equipment reliability is critically important.

5.5 TRAINING NEEDS

Training is a major concern and a major focus for the Hydrology Division. Upgrading field and office skills through supervision, review, and assessment of work products is the principle training method. Additional training needs include:

- Basic hydrology and hydrometric monitoring for Technicians
- Installation, use and maintenance of OTT Thalimedes data loggers,
- Awareness of the importance of hydrologic data for Technicians and Technical Assistants
- Current gauging using conventional current meter methods as well as newer technology such as the Acoustic Doppler Current Profiler.

The USAID/OKACOM Project can support the training needs to improve hydrologic monitoring through inclusion of Namibian Technicians and Technical Assistants in regional training programs as proposed in Section 7 of this report.

6. CONCLUSIONS: CRITICAL GAPS IN HYDROLOGICAL MONITORING BACKGROUND

Hydrologic monitoring in all three riparian countries in the Okavango River basin is being managed by a division of the national agency responsible for water resources management. In all three countries this national agency also plays a significant role in water supply. Only in Botswana is hydrologic monitoring decentralized with responsibility delegated to regional offices within the Okavango River Basin (Maun and Gumare). In Angola, DNA is currently responsible for all but major urban water supply, but with plans to hand over major responsibilities to public companies and provincial government. In Botswana, the Department of Water Affairs continues to have responsibility for operating and maintaining supplies in major villages and designing and building schemes for villages (which are then turned over to district councils for operation and maintenance). In Namibia, the Namibia Water Company Ltd (NamWater) was recently separated from DWAF but the Department continues to be responsible for establishing small rural water supply schemes throughout the country. In Angola and Botswana particularly, it appears that the immediate practical and political pressures to provide water for human consumption is higher priority than collecting and verifying the accuracy of hydrological data. In Angola budgets are not sufficient to plan and undertake regular field trips to visit stations and collect information. In Botswana data collection and management is left largely in the hands of Technicians. Namibia appears to have a firm commitment to long-term hydrologic data collection that includes regular, rigorous checking and validation of results by trained hydrologists.

In all three countries much, if not all, field work related to hydrologic monitoring including making level readings, replacing level recording charts, downloading data loggers, and completing river gauging, is the responsibility of hydrometric Technicians and Technical Assistants. Responsibility for specific hydrometric monitoring tasks is shown in Table 6.1. Logistical factors weigh heavily on how data are collected. In Angola, DRH is extremely understaffed with only eight Technicians operating out of four offices to cover only nine of Angola's eighteen provinces. At present, no staff are assigned to Kuando Kubango Province in which most of the Angolan part of the Okavango River basin lies. Although there are plans expanding the hydrological network, it is not clear how this can be achieved without a significant increase in staffing and operational budgets. In Namibia, data collection is completed by Windhoek-based technical staff that must drive 700 km to take readings and collect digital data at Rundu and Mukwe. With perennial rivers only at the extreme borders of the country and with limited need for field work through most of the year on ephemeral rivers, it is hard to justify a large technical staff. Only Botswana has been able to focus resources in the basin, with regional offices and hydrology sections in Maun and Gumare and a permanent camp at Mohembo. But even in Botswana the difficulties of travel in and around the Delta are obstacles to regular monitoring at many sites.

Professional staffing related to hydrologic data collection and use of the data varies significantly in each country. In Angola, the Director of DRH, Mr. Paulo Emilio Mendez, is the only professional with any formal hydrology training. He will be eligible to retire within the next several years leaving the Department in need of successors with his experience and skills. Identifying and training hydrologists should be a high priority for Angola. Similarly, in Namibia several of the senior managers including Mr. Piet Heyns (Undersecretary of DWAF), Mr. Stefan de Wet (Acing Director of Resource Management), and Ms Antje Eggers (Chief Hydrologist in the Surface Water Database Subdivision) will be eligible to retire soon with Mr. Guido van Langenhove (Deputy Director of the Hydrology Division eligible in the foreseeable future. Although the Hydrology Division has eleven posts for Hydrologists (8 filled at present) it is not clear if any of these hydrologists have the experience to step into management positions and retain commitment to hydrologic data collection, verification, and archiving.

Table 6.1: Hydrometric Monitoring Responsibilities

Function	Responsibility		
	Angola	**Botswana**	**Namibia**
Overall management of data collection	Mr. Paulo Emilio Mendez, Director Departamento Recourcos Hídricos, DNA	Mr. Tapson Bombo, Supervising Technical Officer, Hydrology Division, DWA	Mr. Guido van Langenhove, Deputy Director Hydrology Division, Directorate of Resource Management,

			DWA
Establish station, install instrumentation	Senior Technician and Technicians (note, no distinction is made between Technicians and Technical Assistants) with oversight provided by the Director DRH	The Officer in Charge in the region assisted by Technicians and Technical Assistants	Technicians or in some cases Technical Assistants. Note that NamWater have also installed some stations
Take level readings	Technicians often accompanied by a Senior Technician or the Director DRH	Technical Assistants Note some level readings are read by volunteers such as lodge owners in the Delta	Technical Assistants sometimes with supervision by Technicians. Note NamWater takes readings at dams
Replace charts	Technicians often accompanied by a senior Technician or the Director DRH	Technical Assistants	Technical Assistants sometimes with supervision by Technicians
Collect digital data (HYCOS, Thalimedes, etc)	For HYCOS: Technicians by replacing memory module and bringing the module to the Luanda office. For Thalimedes: Technicians by downloading in the field using the Vota2 processor.	Technical Assistants	Technical Assistants sometimes with supervision by Technicians
Check, rest offsets	Technicians often accompanied by a Senior Technician or the Director DRH	Technical Assistants	Technical Assistants sometimes with supervision by Technicians
Manage gauging	ADCP: Best Technician (Narciso) accompanied by other Technicians and the Director DRH Current meter: Senior Technician accompanied by other Technician and often by the Director DRH	Senior Technical Assistant with most of the field work done by gauging assistants	Senior Technician often accompanied by the Deputy Director Hydrology Division since it is not done that often
Calculate discharge	ADCP: Automatically calculated by computer Current meter: Senior Technicians with oversight by the Director DRH	Technicians in the field when gauging is being completed	Technicians at DWA office in Windhoek, using data collected in the field

Check/validate data	Senior Technicians with Technicians with assistance of Director DRH. Final approval by Director DRH	Hydrology Section Officer in Charge in the regional office and Chief Technical Officers in DWA office in Gaborone	Technicians and Hydrologists in the DWA office, Windhoek with additional checking by Surface Water Database Subdivision staff
Enter data into database	HYDATA 4.2: The Department Economist who was trained for this task. Note: Special software was developed to transfer data from the Vota2 directly to the Hydata database	HYDATA 4.2: Data Entry Clerk	Surface Water Database Subdivision staff Hydstra 9.1 (note: there are newer versions available)

A more formal mentoring program for younger Namibian hydrologists, if not already established, should be implemented to ensure capacity exists into the future. In Botswana, the Department of Water Affairs' Hydrology and Water Resources Division is staffed by nine professionals at headquarters in Gaborone. It appears that most are heavily engaged in project management tasks, do not routinely get to the field except on project related work, and do not focus on hydrologic data except when needed for analysis related to project development. Hydrologists are not routinely assigned to review, correct, or edit data as part of regular support for the data collection and management process. In Botswana, hydrologists should ensure that data are checked and verified before it is archived in the database.

Technician qualifications are different in each of the three countries. In Angola, where the educational system is different than in Botswana and Namibia, Technicians should have at least pre-university training, but the requirements have been relaxed because salaries are low and opportunities for advancement are limited. As a result, the DRH is willing to accept general secondary school graduates and provide specialized training, largely on-the-job with occasional formal training as opportunities arise. In Botswana, entry level Technicians must have a Diploma in a related field, although it is possible for an experienced Technical Assistant to qualify for lower level Technician posts. In Namibia, a Diploma is required to qualify as a Technician. In all three countries, multiple opportunities are open to qualified Technicians, so it is hard to retain them due to low government salary scales, particularly in Angola. In all three countries, formalized hydrology and hydrologic monitoring training is not a part of the Diploma (or pre-university in the case of Angola) training. The national requirement for hydrometric Technicians is not sufficient to justify a specialized course in any of the three countries. As a result, even the most qualified entry level Technicians need additional training related to hydrology and hydrometry. Such training has been a feature of Department training programs with the most regular training program in Botswana. Namibia does not hire many new Technicians and does not find it cost effective and so teaches the course on an as needed basis. In Angola, all in-house training stopped some ten years due to constraints imposed by the war. A more rigorous review of in-house Technician training programs would provide an opportunity for each department to compare training programs and adopt best practices for the benefit of Technicians engaged in hydrometric monitoring. A more formal compilation of training materials used for the training conducted in each country is needed. As these Technicians manage the data collection process, Project training that focuses on data management including checking, correcting and, verifying should improve data quality.

Technical Assistants or artisans as they are referred to in Botswana are non-Diploma staff who are secondary school leavers. In Angola, the distinction is not made formally, but younger, less experienced Technicians are recognized as such and are supervised by more senior Technicians. This group provides the core of staff that actually go to the field on a day-to-day basis to visit gauging stations and collect water level data. The reliability and accuracy of their work is critical to the hydrologic data collection process. Training for this group is entirely in-house with classroom training provided by department Hydrologists or Technicians and field training provided by Technicians or more experienced Technical Assistants. Technical Assistants are not well paid by the standards of the countries where they work and only in Botswana can they become Technicians and improve their salaries. The Project should focus on Technical Assistant training that improves skills and enhances pride in field performance, which should improve data quality.

Instrumentation in use is slightly different with Angola making the biggest commitment to digital data collection platforms. With nearly all stations in the country needing repair and upgrading, the opportunity to move decisively toward modern data collection techniques was seen and taken. Although Angola has been able to reestablish monitoring at only eleven stations, all are equipped with data logging instruments including the HYCOS DCPs, OTT Thalimedes data logger and one OTT pressure probe. Angola also has an Acoustic Doppler Current Profiler (ADCP) for gauging, determining discharge, and developing site rating curves. Some fifteen more OTT Thalimedes are ready for installation. Botswana, while an early convert to digital data collection in the 1990s, found that first generation digital data collection equipment was not reliable and have, until now, relied largely on analog chart recorder for recording water levels. A recent foray into modern equipment, the OTT automatic gauging station at Mohembo, is not operational so it is not surprising that some skepticism remains. However, there is agreement that digital equipment would be a step forward if it were reliable. Namibia has taken a middle course with the recent introduction and trial of OTT Thalimedes data loggers. These are being run in parallel to chart recorders to see if they are reliable enough to replace the chart recorders completely. No plans are in place to abandon chart recorders at present, but there is recognition that eventually parts for the recorders they have will be hard, if not impossible, to obtain. These different experiences suggests that opportunities for each country to be exposed to new equipment and learn from the experiences of the others through cross visits and

joint training. The Project should actively support cross visits and joint training exercises for both Technicians and Technical Assistants to introduce them to the equipment and field practices in use in other countries in the basin.

The Department of Water Affairs and Forestry in South Africa is the implementing agency for the HYCOS Phase II Project. One of the main components of the Project is training; much of it associated to the installation, operation, and maintenance of the HYCOS DCPs. In addition, the Department of Water Affairs and Forestry offers a two week introduction to hydrometry as well as specific hydrometry training modules at their facility near Pretoria. Under HYCOS Phase I, only two Technicians from each participating country were trained in the operation and maintenance of HYCOS DCPs. With attrition in Technician ranks, this has not proved sufficient. This provides the USAID/OKACOM Project with two specific opportunities to support Technician and Technical Assistant training within the basin. First, the Project should consider sponsoring additional Technicians for HYCOS training to ensure that trained Technicians familiar with HYCOS system operation and maintenance are available within each country. Second, the Project should revisit the possibility that some courses offered by the Department of Water Affairs in South Africa could be valuable to Technicians and Technical Assistants working in the basin. Although Botswana indicated that they have courses equivalent to those offered by in South Africa and Namibia felt that conditions and practices taught were not compatible with Namibia's dry conditions, Angolan Technicians have found the hydrometric training modules to be valuable. If the courses available in South Africa are seen by national hydrology departments to meet specific basin hydrometric training requirements, the Project should consider sponsoring attendance at one or more of these short courses or training modules.

Finally, the recent availability of ten years worth of data from the Kubango catchment, even though it is for the period between 1963/4 and 1973/4, provides an opportunity to study the upper Okavango hydrologic system and relate it to stations with longer periods of record in Namibia and Botswana in a way that was hitherto not possible. Such a study would begin a process leading to a better understanding of the hydrology of the entire river basin. A well defined basin wide hydrologic study utilizing available data from all three riparian countries should be supported.

7. PROPOSED TRAINING ACTION PLAN

The Proposed Training Action Plan, described below and summarized in Table 7.1, derives from interviews and field visits in Angola, Botswana, and Namibia, discussions with Hydrologists, Technicians, and Technical Assistants, and focused discussions with the responsible Hydrologist in each country[31]. Major findings and conclusions were discussed with each individually. The consultant had the opportunity to meet with the three Hydrologists as a group during part of the field trip to Rundu, Namibia and Mohembo, Botswana and again in an evening meeting during the OKACOM meetings in Windhoek which took place in late October 2005. These meeting provided the opportunity to discuss strengths and weaknesses of each country's hydrologic data collection program with discussion of issues beyond the control of the organization each represented. These issues included such items as salary levels and the need for a career ladder so that qualified staff can be attracted and retained, and logistical issues related to distances that must be traveled to collect information. Consensus was readily reached that reestablishing hydrometric monitoring in the Angolan part of the basin was the first priority and a second priority was to complete rating exercises to allow discharge calculations for new stations in Angola and improve calculations for existing stations in Namibia. Consensus was also reached regarding the benefit of Technician and Technical Assistant cross visits as a way to observe and develop skills and improve hydrometric practice. All believed that focusing on Technicians and Technical Assistants would help raise the profile of the work they were performing, provide incentives for reliability and accuracy, and help engender pride in the critical part they play in collecting and processing the information required for basin-wide planning.

Due to the differing capacities of the cadre of Technicians and Technical Assistants, the proposed training action plan also includes recommendations for specific training to improve data collection, processing and archiving in each country. These recommendations derive, not only from the three responsible Hydrologists, but also from others interviewed and the consultant's observations. The Proposed Training Action Plan is organized by regional training and then country specific training. A tabular summary is provided in Table 7.1.

7.1 PROPOSED REGIONAL TRAINING

Although each of the riparian countries has training needs, each also has its strengths that provide opportunity for observing best practice, and improving coordination and relationships though cross-visits, and collaborative data collection exercises. These opportunities not only improve skills, but also foster understanding and help develop trust among the three national agencies that collect primary hydrologic data. Note that following discussion about differences between discharge figures for Mukwe and Mohembo in the 1980s, several joint gauging exercises were undertaken that allowed hydrologists to understand these differences, helped foster understanding between the two agencies, and allowed each to see what differences there were in how they collected data. With the goal of improving hydrologic data collection and fostering greater understanding among the Hydrologists and Technicians of each country, the following training is proposed.

ADCP Joint Demonstration and Measurements

Angola is the only riparian country to have and use an Acoustic Doppler Current Profiler (RD Instruments- Rio Grande 600, River Direct-Reading ADCP). The instrument has the capability to instantaneously measure river discharge while crossing the river in a boat. The technology is particularly interesting because it is fast and reliable, allowing accurate discharge measurements to be made in a matter of minutes at nearly any location. The hydrology departments in both Botswana and Namibia are interested in the technology which could be used effectively at sites along the Kavango in Namibia and a number of locations on the Okavango in Botswana. The proposed demonstration and training program would not only demonstrate the technology but also provide discharge ratings for unrated sites in Angola and Namibia and provide a check on ratings at Mohembo. The joint demonstration and measurement program should provide for participation of Technicians from all three countries and should complete cross section and discharge measurements at sites in all three countries. Specifically, Technicians should, at a minimum, visit and make measurements at the five sites to be established in Angola (see section 3.2), Rundu and Mukwe in Namibia, and at Mohembo in Botswana.

[31] Mr. Paulo Emilio de Mendez in Angola, Engineer Kalaote Kalaote in Botswana, and Mr. Guido Van Langenhove in Namibia.

Course curriculum: ADCP use in three countries
Instructor: Paulo Emilio de Menendez and Angolan Technicians
Target audience: Hydrologist and 2 Technicians from each riparian country
Course duration: Three weeks

Thalimedes installation and Use

Both Angola and Namibia have procured OTT Thalimedes water level data logging equipment. Botswana is considering a different data logging system-one that can be used in smaller diameter wells, but would appreciate the opportunity to be exposed to the OTT data loggers. Several Technicians and Technical Assistants in Angola and Namibia have received limited training in Thalimedes installation and use. Broader exposure to installation and use of the Thalimedes and demonstration of different downloading procedures would benefit Technicians and Technical Assistants from all three countries. The proposed program could take place in Angola when stations are to be reestablished in the Kubango catchment. The program should include participation of at least one Technician and two Technical Assistants (or Artisans in the case of Botswana) from each riparian country. These Technicians and Technical Assistants should participate in the installation, set-up and initial data collection at each of the five sites to be re-established in the Kubango catchment in Angola. Note this training should be conducted in parallel with OTT Thalimedes Field Installation Training outlined in Appendix 4.

Course curriculum: OTT Thalimedes Installation and use
Instructor: Antonio Pacheco Makete, Chief Technician and Manager for South Region
Target audience: Technician and 2 Technical Assistants from each riparian country
Course duration: Two weeks

River Gauging Practical

Mohembo is the only location in the Okavango basin were a permanent camp has been established allowing daily gauging and discharge measurements. No traditional gauging has taken place in Angola in many years (although the ADCP has been used on several occasions recently) and gauging is rarely completed in Namibia due to the geography and climate. Technicians and Technical Assistants in these countries may learn how to make discharge measurements, but do not have the opportunity to practice and solidify these skills. The Mohembo camp, where measurements are made daily, provides an opportunity for Technicians and Technical Assistants to practice the skills. The proposed program would take place in Botswana at the Mohembo camp and would allow four Technicians and Technical Assistants from Angola and Namibia to work together with their Botswana counterparts over a two week period, participating in gauging exercises including use of the OTT C-31 current meter (in use in all three countries) and completing discharge calculations.

Course curriculum: River Gauging and discharge calculation practical
Instructor: Technician in charge, DWA Camp, Mohembo
Target audience: 2 Technicians and 2 Technical Assistants from each riparian country
Course duration: Two weeks

Hydrologic data processing and archiving

Angola is only beginning to establish rigorous procedures for collection, processing, checking, and archiving digital data. Although some procedures have been established, the fact that the hydrometric staff is small and the number of stations limited means that thorough end-to-end data tracking and processing procedures are not as necessary as they will become once stations are reestablished throughout the country. In Botswana, where procedures are in place, it appears that attention to detail is often lacking. As noted above, Okavango Delta Management Plan consultants recommended a complete overhaul of the routines in water level readings and discharge measurements. Namibia has in place a clear and complete data handling process that provides an opportunity for Hydrologists and Technicians to view data management practice. The proposed program would focus on demonstrating to Angolan and Botswana Hydrologists and Technicians how data are collected, checked and edited, rechecked and approved for archiving so that best practices can be incorporated into programs to improve data quality and reliability.

Course curriculum: Hydrologic data processing and archiving

Instructor: Hydrology Division, DWAF/Namibia
Target audience: 2 Hydrologists and/or Technicians from each riparian country
Course duration: One week

7.2 PROPOSED TRAINING IN ANGOLA

Angola's hydrological training programs are all opportunistic and ad-hoc at present. Although this must change if DRH is going to engage new staff and establish additional gauging stations, this effort is beyond the scope of this Project. The training proposed for Angola continues in the recent tradition of providing training to meet immediate needs. This includes training for two new Technicians who will be engaged to support hydrometric monitoring in Kuando Kubango Province and priority training for other Hydrometry Unit staff.

Focused hydrometric training for new Technicians

Two new Technicians will be engaged to collect data at reestablished stations in the Kubango and Kuito River basins. These Technicians have a secondary education and need basic training in hydrometric theory and practice. A detailed program designed to improve sustainability of date collection in the Kubango catchment is described in Appendix 4. These training courses are included in Table 7.1.

River Gauging using the OTT C-31 current meter

Although Angola has an ADCP for current profiling, most river gauging in Angola for he foreseeable future will still depend on mechanical instrumentation, namely the OTT C-31 current meter. Recently employed Technicians, including those who will be engaged to work in the Kubango catchment, have not learned how to use these instruments. The proposed program would provide these Technicians with practical field experience with these instruments in a short course taught in Portuguese by more experienced Angolan Technicians. Practical work would take place in the field at one or more sites where the results would provide a check on the current rating for the site.

Course curriculum: Flow Gauging using the OTT C-31 current meter
Instructor: Francisco Fernando Miguel, Antonio Pacheco Makete, Chief Technicians, Hydrometry
Target audience: Recently employed Technicians
Course duration: Two weeks

English Language Training

Much of the material on the use and care of hydrometric instrumentation is not available in Portuguese but is available in English. In addition, both Botswana and Namibia are English speaking countries. Three Technicians have received basic English language instruction as part of the NAWASMA Project. This training should be extended to other Technicians with the three who received basic English language training eligible for more advanced training.

Course curriculum: English Language Training
Instructor: Language training institutes in Angola
Target audience: Recently employed Technicians
Course duration: Depends on availability of courses

7.3 PROPOSED TRAINING IN BOTSWANA

Botswana has a well developed hydrometric training program and curriculum as compared to other Okavango basin riparian countries. The program is officially recognized so satisfactory completion can lead to promotion and salary increases. However, weaknesses are recognized and should be addressed. The two that came to the consultant's attention are instrument maintenance and care, particularly for digital instrumentation, and improved awareness of data use. Both should be addressed by developing and introducing new modules into the training

curriculum. As noted above, any training programs considered for Botswana should be coordinated with the Okavango Delta Management Plan Project that is also developing a training program.

Digital instrument care and maintenance

The two Technicians trained by the SADC-HYCOS Phase I program are not longer available to the Department of Water Affairs and the Okavango Delta Management Plan Project is preparing to procure and install more than 50 digital data loggers for recording surface and groundwater water levels at various locations in and around the Okavango Delta. The United States Geological Survey data loggers and the OTT automatic gauging station are installed, but not operating. The Department of Water Affairs will need technicians who have the skills and abilities to operate, maintain, trouble-shoot, and repair this instrumentation. A training module should be developed to introduce technicians to digital hydrologic monitoring equipment basics with specific attention to equipment in use in Botswana so that they can operate and maintain the equipment so that it can provide a long service life.

Course curriculum:	Operation, maintenance and repair of digital equipment
Instructor:	Polytechnic teacher or equipment representative initially
Target audience:	Technicians, Artisans and Gauging Assistants
Course duration:	One week

Improved awareness of data use

Botswana has a well defined training program that introduces Technicians, Artisans, and Gauging Assistants to the theoretical and practical aspects of hydrologic monitoring. What is lacking and can be addressed is a clearer understanding of how the data that these individuals collect area used and why precision and accuracy are important. The proposed module would demonstrate the use of data in the hydrologic cycle model that is being developed by the Department of Water Affairs and the Okavango Delta Management Plan Project. The training module should describe the model and its purpose and specifically demonstrate how results are skewed when poor quality data are used. It should stress the importance of following data collection and processing procedures carefully.

Course curriculum:	Awareness of data use (a training module)
Module Development:	Okavango Delta Management Plan and modeling specialist
Instructor:	Hydrology Division modeling unit staff
Target audience:	Recently employed Technicians
Course duration:	Two days

7.4 PROPOSED TRAINING IN NAMIBIA

Due to the small staff and lack of clear career enhancement resulting from formal training, most training for Technicians and Technical Assistants is provided in short workshops or on-the-job. As a result few Technicians and Technical Assistants have the skills for day-to-day management of the hydrometric network (with the exception of discharge measuring as noted above).

Awareness and Motivational Training for Technical Assistants

A continuing priority for the Hydrology Division is to maintain quality in the data collection process. An increased awareness among Technicians and Technical Assistants of how data are used would help provide motivation to keep data collection and processing standards high. The proposed program would bring the awareness of data use module developed for inclusion in Botswana's training curriculum to Namibian Technicians to demonstrate Okavango Delta model and what the impact of poor data might be on the scenarios that the model was developed to demonstrate.

Course curriculum:	Awareness and motivational training
Instructor:	DWA/Botswana Hydrology Division modeling unit staff
Target audience:	Technicians and Technical Assistants

Course duration: Two days

7.5 TRAINING PROGRAM PRIORITIES AND SEQUENCING

Training new technical staff to be assigned hydrologic data collection responsibilities in the Kubango catchment is clearly first priority. Training should begin as soon as possible after these staff are hired. Methodological training, the Kunene Province practical, and computer training could take place prior to delivery and installation of equipment. ADCP Joint Demonstration and Measurement should take place during February –March when river flows are high and the program most beneficial for all concerned. The River Gauging Practical should take place before full recession takes place in August or September. This training could be repeated in following years. The Regional OTT Thalimedes Installation and Use training must be coordinated with the installation and set-up of the equipment procured by the USAID/OKACOM Project for the Kubango catchment. Hydrologic data processing and archiving can be arranged at any time convenient for each agency, most probably during the dry cycle in Botswana and Namibia when field work is a minimal. Training proposed for national agencies should take place as time and opportunity for collaborative efforts or maximum benefit arise.

Table 7.1 Training Action Plan Summary

Training program	Instructor (s)	Target Audience	Course Duration	Venue
Regional Training				
ADCP Joint Demonstration and Measurement	Paulo Emilio de Mendez and Angolan technicians	Hydrologist and 2 Technicians from each country	Three weeks	River locations in Angola, Botswana and Namibia
OTT Thalimedes installation and use	Chief Technician DRH, Angola	Technician and 2 Technical Assistants each country	Two weeks	Five new gauging stations Kubango catchment
River gauging practical	Technician in charge, DWA/Botswana Mohembo camp,	2 Technician and 2 Technical Assistants each country	Two weeks	DWA Camp, Mohembo Botswana
Hydrologic data processing and archiving	Hydrology Division staff, DWAF, Namibia	2 hydrologists from each country	One week	DWAF offices, Windhoek
Angola				
New Technicians- *Methodological training*	*Paulo Emilio de Mendez*	*New Technicians hired for Kubango catchment monitoring*	*Two weeks*	*Luanda, DRH offices*
New Technicians- *Kunene Province Practical*	*Chief Technician DRH, Angola*	*New Technicians hired for Kubango catchment monitoring*	*One month*	*Field sites in Kunene Province*
New Technicians- *Computer skills training*	*TBD*	*New Technicians hired for Kubango catchment monitoring*	*TBD*	*Menongue if possible*
New Technicians-*Field installations and initial discharge measurement*	*Chief Technician DRH, Angola*	*New Technicians hired for Kubango catchment monitoring*	*Two weeks*	*Field sites in Kubango catchment*
New Technicians- *Follow-up training and support*	*Chief Technician DRH, Angola*	*New Technicians hired for Kubango catchment monitoring*	*One week on three occasions*	*Field sites in Kubango catchment*
River gauging using the OTT C-31 Molinete	Chief Technicians DRH, Angola	Recently hired Technicians	Two weeks	Selected river sites near Luanda

English Language Training	Language training institute	Recently hired Technicians	TBD	Luanda and/or Provincial towns
Botswana				
Digital instrument care and maintenance	Senior Technical Officers and/or manufacturer's representatives	Technicians, Artisans and Gauging Assistants	One week	DWA Training Center
Improved awareness of data use	ODMP Modeling staff	Artisans and Gauging Assistants	Two days	Field offices in Maun and Gumare
Namibia				
Awareness and motivational training	DWA/Botswana hydrology Division modeling unit	Technicians and Technical Assistants	Two days	DWAF offices, Windhoek

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1.2. ANGOLA

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1.4.

1.5. NAMIBIA

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APPENDIX 1: PEOPLE CONTACTED

1.6. ANGOLA

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1.7. BOTSWANA

OKACOM/OBSC

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1.8. NAMIBIA

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APPENDIX 2: FIELD TRIP REPORT: CABIRI AND BOMJESUS, ANGOLA

1.10. PARTICIPANTS:

Paulo Emilio Mendez: Director Department of Hydraulic Resources, DNA and field visit host
Carlos Andrade: Water Resources Specialist, Ministry of Energy and Water
Keith Kline: USAID/OKACOM Okavnago River Basin Project CTO
Jonathan Hodgkin: Project Consultant

1.11. CABIRI:

The monitoring location is at a point along the dirt road just as it enters the village of Cabiri on the south bank of the Bengo River about 30 km from Luanda. The Cabiri gauging station is a HYCOS Enhanced Data Collection Platform which was installed during the HYCOS project. The site is about 20 km below the Quiminha dam. DNA has been collecting data at this site since the early 1950s. The HYCOS instrumentation was installed in February 2001. The Platform instrumentation included sensors for water level, water temperature, turbidity, conductivity, solar radiation, wind speed and wind direction, air temperature and relative humidity. Information is collected in digital form, transmitted via satellite to the HYCOS Pilot Regional Center at DWAF in Pretoria South Africa and stored on a data module for downloading in Luanda.

Stilling well and enclosure for a chart recorder at Cabiri (note the aquatic vegetation)

Roof of the HYCOS station, note that the wind speed sensor is broken

We arrived at the site in the late morning of Wednesday, October 12, 2005. Visual inspection revealed that the wind speed sensor was broken with parts missing. Also invasive aquatic weeds cover most open water near the stilling well and across to the opposite river bank. Other sensors, the aerial, and the photovoltaic panel appeared to be in good order. It was not clear if the turbidity sensor was in place as originally planned for this site. Carlos discovered that bees had taken up residence in the enclosure at the top of the stilling well, so we did not inspect the well. Equipment at the site included an Aurore 200 datalogger, a Serpe-ISEM satellite transmitter, and a memory module. Except for water level, conductivity, and water temperature all sensors are mounted on the structure housing the datalogger and transmitter (see photo). Battery voltage was good (13.4v) and all sensors

except wind speed and water level appeared to be working properly[32]. Paulo was able to confirm that sensors other than water level and wind speed were providing reasonable readings although we could not confirm that data was being stored nor did we confirm that satellite transmission was occurring as designed.

The data module was not replaced, so recent data collected on the module was not available upon return to DNA in Luanda.

1.12. MINEA TRAINING CENTER

We stopped at the MINEA training center which is just east of Cabiri before reaching Katete. The site was at one time an extension center for the Ministry of Agriculture and used to provide training in cotton production. The site came into the possession of the Ministry of Energy and Water. It appears that the Ministry is not certain how best to take advantage of the facility. Most of the buildings on the site are in poor condition with part of the facility used for storage and mechanical repair for deep well drilling and groundwater development equipment. Three drill rigs, all in non-functional state, drill rod, well screens, and perhaps several hundred India MarkII handpumps were in evidence at the facility. The facility is not suitable for hydrometric training.

One of several training center buildings

1.13. BOMJESUS:

The Monitoring location is behind the BomJesus water bottling plant just downstream from the plant's floating off-take pumps on the north bank of the Kuanza River. The BomJesus gauging station is equipped with an OTT Thalimedes float operated shaft encoder and datalogger. This Thalimedes was installed in combination with an OTT water level chart recorder Type X.

Chart recorder in enclosure and Thalimedes data logger being held

Stilling well and enclosure for a chart recorder at BomJesus on the Kuanza

[32] HYCOS-Phase II staff told us that the pressure transducer used with the HYCOS stations was not a good choice and water level sensors have been replaced or are not working at a number of HYCOS sites in the region.

A split staff gauge is also installed with lower part of the staff on a wall that originally allowed readings at low water. Site conditions have changed over the year and today the staff gauge is buried and not visible below 3.5 meters. The upper part of the staff gauge is mounted on the side of the stilling well that enters the ground 2-3 meter from the waters edge. The well is connected hydraulically to the main river.

We arrived at the site in early afternoon. Inspection of the chart indicated that the chart was designed for one month operation. It was last changed in June 2005. The ink in the chart pen had run, making a wide mark on the chart (See photo). Close inspection revealed that a clear pen line could be discerned within the wide area where the ink had run. We did not change the chart paper, or replace the pen or the ink cartridge. Visually, the Thalimedes unit appeared to be in good order. However, we were unable to download the data using the OTT Vota2 data processor with the optical reading head. We were unable to confirm if the Thalimedes was recording water levels as designed as the LCD display could not be activated. Later trouble shooting revealed that the batteries in the Vota2 were discharged. Although we determined that this might be the case while in the field, we did not have spare batteries with us.

APPENDIX 3: FIELD TRIP REPORT: OKAVANGO AREA, NAMIBIA AND MOHEMBO, BOTSWANA

1.14. PARTICIPANTS:

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Samfried Riruako, Chief Technical Assistant, Hydrology Division, DWAF
Kalaote Kalaote: Principle Water Engineer, Hydrology Division, DWA, Botswana (Joined in Mohembo, Botswana)
Jonathan Hodgkin: Project Consultant
Lynnette Wood: Project Consultant (Friday and Sunday only)

1.15. ITINERARY:

Friday, October 28, 2005: Von Bach Dam, Omatako Dam, Southern terminus of the Grootfontein-Omatako Canal, Northern origin of the Grootfontein-Omatako Canal
Saturday, October 29, 2005: Rundu HYCOS station, Rundu level station at NamWater pump station, Mohembo gauging station, Popa Falls, Divundu cableway, Mukwe level station
Sunday, October 30, 2005: Revisit Rundu HYCOS station, Rundu level station with Mr. Kalaote

1.16. VON BACH DAM

Arrive 10:00 AM. The Von Bach dam is one of the main sources of drinking water for Windhoek. A water treatment plant lies just downstream of the dam with treated water being pumped to Windhoek. This dam on the Swakop River has a 49 MCM capacity with a direct catchment area is 2,520 km2. It was completed in 1970 and last overflow release was in 1976. Water is also pumped to this dam from the downstream Swakoppoort dam and the Omatako dam and stored here as this has the best storage characteristics of the three dams (best volume to surface area ration, and hence lowest volume lost to evaporation, a major consideration). Instrumentation at the site includes a gauge plate, an Alpina chart recorder (OTT compatible), and a recently installed OTT Thalimedes. DWAF visits the dam every three months to take readings and replace charts, taking the data for the previous three months back to Windhoek for checking and archiving. NamWater takes daily level readings using the gauge plate. This data are used to check and edit the recorded data. During the visit, the Technical Assistant accompanying us checked water levels, marked the chart, and entered relevant information into the log book that was stored in the instrument enclosure.

Enclosure and chart recorder on the intake structure of the Von Bach Dam. A Thalimedes is installed here as well

1.17. OMATAKO DAM

Arrive 12:45 PM. The Omatako dam, on the Omatako

Instrument enclosure on the intake structure of the Omatako Dam

River, just south of Okakarara, was completed in 1982. It has a capacity of 45 MCM with a direct catchment area of about 5,000 km2. The Omatako River is technically within the Okavango River basin, but at no time in memory has water flowed to the river-pooling and evaporating well before reaching the Okavango River. When visited the water level was very low with the pipelines used to pump dead storage visible (See photo). However, the dam does overflow more often than the Von Bach dam. As this dam has relatively poor storage characteristics, water is pumped to the Von Bach dam for storage. The terminus of the Grootfontein-Omatako Canal is at the dam, with water flowing into the dam from the canal (see below). DWAF is not monitoring water levels in this dam. NamWater, who operate the dam, collect water levels for their own water management purposes.

1.18. SOUTHERN TERMINUS OF THE GROOTFONTEIN-OMATAKO CANAL

The Grootfontein-Omatako Canal is a part of the Eastern National Water Carrier that currently conveys water from groundwater wells just south of Grootfontein and mines in the Otavi mountain area to rural areas in the Okakarara District and to the Omatako dam. This gravity flow canal runs for some 263 km, of which 203 km is an open concrete-lined parabolic section with the remainder being inverted siphons or underground pipeline. The canal was completed in 1983 as what was then part of a longer term plan to extend the system to Rundu as an emergency supply for the central districts of the country. The design flow of the canal is 2.6 m3/sec with a maximum delivery of 80MCM annually, roughly four times the current consumption of Windhoek. DWAF is not monitoring flows in the canal, but we took the opportunity to see the radar sensor used by NamWater to monitor water levels in the canal. Issues related to accuracy and interference during rainstorms were discussed among the assembled group.

Inspecting NamWater's radar water level sensor

1.19. NORTHERN ORIGIN OF THE GROOTFONTEIN-OMATAKO CANAL

Arrive 5:00 PM. The northern end of the Grootfontein-Omatako Canal is near the road about 15 km south of Grootfontein. The design of the canal at the head end reinforced the notion that the canal was overbuilt. A Parshall flume was built into the system within meters of the origin of the canal. Water was being pumped (metered) from a nearby deep well, apparently with the major goal being to keep water in the channel so that hydrostatic forces will not damage the canal during heavy rain events anywhere along the canal. The flume has been fitted with a v-notch weir as the flow as not sufficient for use of the flume. As indicated above, the long term plan was to extend the Eastern National Water Carrier to Rundu, some 240 km to Rundu. But construction costs and pumping costs (some 800 meters of head to overcome from the Okavango to the origin of the canal) are among the reasons for seeking other alternatives for providing emergency water to the central districts. As at the terminus, DWAF is not monitoring water level or flow at this location. NamWater does have a radar water level sensor at the location with telemetry to provide real time information for their purposes.

Viewing the V-notch weir at the northern end of the Grootfontein-Omatako canal

1.20. RUNDU HYCOS STATION

Arrived 8:30 AM Saturday. The Rundu HYCOS station is one of Namibia's Enhanced Data Collection Platform with instrumentation for water level, water temperature, turbidity, conductivity, solar radiation, wind speed and wind direction, air temperature and relative humidity. The station is located along the Okavango River near a lodge with a night watchman who watches over the lodge and the lodge's pump nearby. The station was moved to this location after vandalism at the original location near the Rundu level station at the NamWater pump station. No damage to the station has occurred at this site. Instrumentation was operating at the site with the recent replacement of the water level pressure probe. It was pointed out and discussed that the instrumentation readout provides only current readings, and do not allow on-site review of the data stored in the memory module. We also discussed the fact that the HYCOS Phase I program provided identical packages to for each of the fifty stations provided to the 10 participating countries, with standard cable lengths and insistence the solar power be used even though mains electric power was available at the site. The HYCOS sites in Namibia were installed in collaboration with the Department of Meteorological Services (who hold the satellite transmission license) with the Hydrology Division interested almost exclusively in water level and to some degree with rainfall. No gauging has ever taken place at this site. The flood of 2004 reached about a meter above the base of the station enclosure, with the water level above the bottom of the instrumentation enclosure box just below the instrumentation connection point. We returned to the site on Sunday morning so that Mr. Kalaote could see the site as well.

Relocated Rundu HYCOS station on the Kavango River

1.21. RUNDU LEVEL STATION

Arrived 8:45 AM: We saw the first HYCOS site where vandalism caused the relocation of the equipment. The site was built on the base of an old gauging cable way which was destroyed by the military during the Angolan war. Vandalism was not malicious, but a concerted effort to remove the security door and building materials. We then proceeded to the pump station and the location of DWAF water level instrumentation. Instrumentation at the site includes an Alpina water level chart recorder, an OTT Thalimedes digital data logger and a gauge plate. Water levels records at this site stretch back to 1946. As at Van Bach dam, DWAF visit the site, visits are made every three months to take readings and replace charts, with charts taken back to Windhoek for checking and archiving. NamWater also take daily level readings using the gauge plate. As at the Von Bach dam, during the visit, the Technical Assistant accompanying us checked water levels, marked the chart, and entered relevant information into the log book that was stored in the instrument enclosure. We retuned to this site on Sunday so

Inspecting the Chart Recorder and Thalimedes at NamWater's Rundu facility

that Mr. Kalaote could see the OTT Thalimedes instrument and discuss its operation and cost with Mr. Langenhove and Mr. Mendes who have experience with the instrument. The last gauging at this site took place in 1976.

1.22. MOHEMBO GAUGING STATION

Arrive at 2:00 PM: Mr. Kalaote introduced us to Mr. Baeti, the Officer in Charge of hydrology section in Maun and Mr. Makumbe, the Technical Officer in charge at the Mohembo Camp. Mr. Makumbe explained that the camp is permanent with a full complement of ten including two technicians, laborers, vehicle and boat drivers and watchmen. The camp staff rotate in an out from the Gumare Regional Office on about a two week basis. From the Gumare Regional Office, the current list of stations being monitored include about 20 with half being flow gauging stations with discharge measurements and calculations are made. The Mohembo camp staff complete a gauging exercise every day using an OTT C-31 current meter with a boat and rope system. The process takes about an hour and a half daily. A new automated OTT automatic cableway system has been installed but is not currently operational due to accidental damage during installation. Water level instrumentation at the site includes a Stevens chart recorder and a gauge plate. A HYCOS DCP is also located at the site. It was interesting to note that the DCP was not enclosed in a building. There was no need as the site is secure. There is also an STS data logger at the site. This was a first or second generation data logger installed some ten years ago. The station is not functioning but the solar panel is still connected. Mr. Mendes asks about the HYCOS water level probe, when it was last replaced (February) and whether they repair or replace them (replace them from European supplier). He also asks if they have and OTT Thalimedes data recorders (no, Botswana has no experience with the Thalimedes). We discussed sediment studies. We were led to believe that Okavango Delta Management Plan Project would complete some studies. There is a grab sampler at the Regional Office in Gumare.

Kalaote Kalaote, Guido van Langenhove, and Paulo Emilio Mendez a Mohembo. Note stilling well and instrument enclosure in the background

1.23. POPA FALLS

Arrived 4:15 PM: Popa Falls was the proposed site for a 20MW hydropower facility. The "falls" are more like a small rapids; Mr. Mendes was amused that such a site, with an 8 meter head, would be considered for a hydropower project. The Angolan perspective, with abundant national water resources, is very different than in either Namibia or Botswana. The proposed project at this site was called into question by environmental issues and sedimentation concerns. A second location, with an even lower head was also considered. At this time, there are no concrete plans to develop the site.

Near the Popa Falls site proposed for a low head hydro facility

1.24. DIVUNDU CABLEWAY

Arrived 4:45 PM: The OTT cableway at Divundu was installed in 1974. The site is at a stable confined section about 20 km from the Mukwe level station. The river is about 125 m across at the site. The cableway has now been out of service for two years. Repairs do not look too difficult except that the repair procedure is likely to require OTT factory oversight and expensive equipment. Repairs are being contemplated but are not yet planned. When operational, a gauging at the location could be completed in three to three and a half hours. Discharges are calculated based on the Divundu section and the Mukwe water levels. Until the cableway broke, velocity measurements were made at the site four times a year. Discharges range from about 90 m3/s to some 800 m3/s.

1.25. MUKWE LEVEL STATION

Arrived 5:30 PM: The station is a level recording station with a continuous record since 1949. The site is downstream from the confluence of the Okavango and Cuito Rivers and allows measurement of the maximum flow in the Okavango River. Instrumentation at the site includes a battery operated OTT chart recorder and an OTT Orphimedes data logger. There is a gauge plate at the site too. As at Von Bach dam and Rundu, the Technical Assistants accompanying us checked water levels, marked the chart, and entered relevant information into the log book without any prompting. The procedure followed seemed routine and practiced. Both Mr. Kalaote and Mr. Mendez were interested in the Orphimedes data logger, a bubbler type system, with a micro-compressor that generates the air bubbles and records the pressure required generate the bubbles. The system, the only one in use in the basin, appears to be a good solution in the clear, clean water of the Okavango. The system operates on four C cell batteries.

The stilling well and instrument enclosure at Mukwe housing a chart recorder and Orphimedes data logger

1.26. CONCLUSION

The opportunity for the most senior hydrologists involved in water resources monitoring was appreciated by all. The field venues and station visits provided the opportunity for free and open discussion about instrumentation, data collection processes, and exchange of information and ideas. This type of joint field trip should be repeated.

APPENDIX 4: SUSTAINABILITY CONSIDERATIONS AND PLAN FOR ESTABLISHING HYDROLOGIC MONITORING IN KUANDO KUBANGO PROVINCE

1.27. BACKGROUND

Twenty-one hydrologic stations existed in the Cubango Basin in 1974. Today, no operating stations remain. The NORAD-financed project helped DNA's Water Resources Department review and digitize ten years of historical data (roughly 1965-1975) and enter it into a HYDATA database. The Okavango River Basin Commission (OKACOM), recognizing the importance of hydrometric data, gave priority to reestablishing hydrometric monitoring in the Upper Okavango Basin in Angola in Angola's Cubango River Basin. The USAID/OKACOM Okavango River Basin Project in collaboration with the UNDP-GEF Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO) Project agreed to support this priority initiative. The USAID/OKACOM Project and EPSMO worked together with DNA and Provincial staff completed an initial assessment of nine accessible stations[33]. Plans were to visit other locations, but safety considerations prevented this. The report recommended reestablishing hydrologic monitoring in up to 18 stations including monitoring of selected water quality parameters.

Following discussions with DNA's Water Resources Department and Provincial Officials, a decision was made to reestablish monitoring in a phased program beginning with five stations with data to be collected by two technicians employed by the Provincial Directorate of Energy and Water. Initially, the stations selected for rehabilitation were 1) Menonge-Cuebe, 2) Menongue-Luahaca, 3) Cuchi, 4) Kubango, and 5) Cutato. However, with the opening of the road to Cuito-Canavale, this station has been considered as an alternative to Cutato to establish at least one first phase station on the Cuito River. A final decision about Cuito-Canavale will depend on an inspection of the condition of civil works at this station. The IRBM Project will procure the equipment necessary for measuring water levels, establishing river profiles and measuring water velocities as required to calculate water flows. The instruments and equipment will include OTT Thalimedes float operated data loggers and associated equipment for down-loading data (VOTA multi-functional data processor)), and an OTT propeller-type current meter and associated equipment for collecting velocity profiles (a boat, cable, and winch). DNA staff is familiar with this equipment and has decided to standardize on OTT equipment to facilitate training and equipment operation, maintenance and repair. Decisions regarding water quality monitoring remain to be taken and can be included in second phase of the monitoring improvement program. The Provincial Governor has named two technicians to support this hydrologic monitoring program. Minimum qualifications of Habilitações Literárias (Secondary School Leaving Certificate) from a vocational secondary school was established by the Water Resources Department for these technicians.

1.28. INSTITUTIONAL SETTING

The DNA's Water Resources Department has responsibility for archiving national water resources information. In the past, the Department employed staff throughout the country to collect and analyze hydrologic data. Currently, the department is staffed by three professionals (not all hydrologists) and eight technicians who are stations in Luanda and several offices in the south end west of the country. However, the water sector is in a transitional state driven by decentralization and the National Water Sector Strategy. It is not altogether clear at this time how these changes will eventually change the collection and use of hydrologic data. However, it is clear

[33] Initial Field Reconnaissance Report: Rapid Assessment of the Hydrometric System in Angola, USAID/OKACOM Project and EPSMO, June 2005

that some responsibilities will be transferred to Provincial governments. Provincial Governments have established Provincial Directorates of Energy and Water, and Water Departments to mirror the National Department of Water Affairs. These departments are not fully staffed or trained and continue to look to DNA for guidance and technical assistance. The decentralization of services, by naming provincial technicians to fulfill the functions heretofore the responsibility of the National Department of Water Resources, is new development that will increase provincial responsibility for water resources management. However, these technicians need training to enable them to complete their water resource monitoring responsibilities.

1.29. EQUIPMENT INSTALLATION

Installation of the new equipment will depend on repair and rehabilitation of the selected monitoring sites. The Department of Water Resources with assistance of the EPSMO Project is scheduled to make the necessary repairs at the five selected hydrologic monitoring sites. This work will be overseen by the Director of the Department of Water Resources, Paulo Emilio Mendes. This work should be completed in late 2005 or the first quarter of 2006.

As indicated above, the USAID/OKACOM Project will procure OTT Thalimedes float operated data loggers. These will be installed under the direction of DNA staff (Paulo Emilio or perhaps Antonio Pacheco Makete with assistance of one hydrometric technician). It will be important to include the two Provincial technicians in all technical installation activities. At the same time that the Thalimedes are installed, the installation team should record water level, define the river profile at the site, and take current readings to determine river discharge at the site. This will provide an opportunity for the experienced DNA technicians to train the provincial technicians.

1.30. OPERATION AND MAINTENANCE

Operation and maintenance of the reestablished hydrometric stations will be the responsibility of the Water Department of the Provincial Directorate of Energy and Water. Operationally, the two named technicians will collect data from the Thalimedes equipment using the OTT VOTA 2 data downloading and processing unit. The Provincial technicians will be responsible for confirming river profiles and taking current readings on a periodic basis to ensure that accurate discharge measurements can be calculated. Ideally, data should be collected on a monthly basis. However, the Talimededes unit can be programmed to collect and store date over a longer period so that if the hydrometric station cannot be visited during the rainy season, a continuous record can be captured

Data downloaded from the Thalimedes water level recorders using the VOTA 2 must be transferred to computer in Kuando Kubango so that Provincial departments have the information for water resources planning and management purposes in the future. The data should be checked and verified. The data must also be transferred to the national hydrological data base at DNA in Luanda.

1.31. SUSTAINABILITY

Continuing hydrologic date collection will depend on a number of factors. Perhaps the most important of these is the commitment of the provincial administration of Kuando Kubango that, over the long term, must support the operational requirements. Every opportunity should be taken to reinforce the message that availability of continuous discharge data are important for the in-depth hydrological studies that should be completed prior to

approval for major water resources development programs including irrigation and hydropower projects. These studies are important to ensure sustainable management of the basin's water resources.

On the more practical level, sustainability of the water resources monitoring program will depend on:

- Reliable equipment,
- Spare parts for repair of replacement of faulty equipment,
- Trained technicians with the ability to collect and verify data accuracy,
- Vehicles and fuel for visiting the stations and generating velocity profiles,
- Funds for field allowances for technicians,
- Office space for a computer and printer for processing and storing data, and
- Technical guidance and oversight.

The Department of Water Resources has chosen to standardize on the OTT Thalimedes water level monitoring equipment based on their experiences in the recent past. This equipment is widely used in the region and can be purchased through an agent in Luanda (Rocha Monteiro, LDA). The choice is corroborated by the experience of the Department of Water Affairs and Forestry in South Africa who suggest the Thalimedes and VOTA is one of the best water level datalogging systems available on the market today. The OTT current meter is a reliable straightforward velocity meter that has been used for several decades in Angola.

To address the need for spare parts, the Project will purchase an extra Thalimedes unit that should be stored in Kuando Kubango, most logically within the Water Department of the provincial administration. A generally accepted rule of thumb is that over the long term, roughly 10% of the original equipment costs should be budgeted for maintenance and repair costs or roughly $7,000 annually for the equipment provided under the first phase of the program. Note that annual expenditures will likely vary with minimal maintenance and repair costs initially, but increasing as the equipment ages.

Training the two technicians named to support hydrometric monitoring is a critical need. In addition to technical skills related specifically to operation of the data collection equipment, the technicians will need basic computer skills to enable them to manipulate the data once it is collected. The Project will support this training with the assistance of DNA's Department of Water Resources. This will likely be an ongoing process over the life of the Project with training opportunities to include classroom training in theoretical aspects of hydrologic monitoring as well as practical skills development for colleting data, processing it, and evaluating the results. A training program is outlined in the following section.

The ability of technicians to collect, process and analyze data also depends on logistical support including access to transportation to allow visits to monitoring stations, allowances for technician travel that may require extended overnight trips, and office space with a computer to download data, store it, display it and use it within the province. Although some of these requirements may initially be covered either by the Project or the EPSMO Project, eventually they will have to be taken on by the Provincial Administration.

Although the Hydrometric Technicians will be formally employed by the Provincial administration, technical guidance and oversight should be provided by DNA through the Director of Water Resources, Paulo Emilio and his Southern Region Manager, Antonio Pacheco Makete. Periodic visits by one or both of these professionals will help reinforce the training provided and provide an opportunity to refine techniques to improve data collection, verification, and analysis processes.

1.32. RECOMMENDED TRAINING PROGRAM FOR KUANDO KUBANGO TECHNICIANS

The immediate critical need is to upgrade the skills of the recently named hydrometric technicians prior to and immediately following installation of the procured equipment. This program is outlined in the following paragraphs. In addition to the training outlined below, the Kuando Kubango hydrometric technicians should be included in all relevant national and regional training programs.

1.32.1. Methodological Training Luanda

The Director of the Department of Water Resources and senior hydrologist, Paulo Emilio Mendes, has developed a theoretical training curriculum that was used in the past to introduce new technicians to the required theoretical aspects of water resource monitoring. The course also served as a refresher for other hydrometric technicians. He taught the course on a regular basis into the 1990s but has not done so since because no new staff joined the Department. Now that new technicians have been assigned to hydrometric monitoring, this course should be reviewed and updated as necessary and then taught to the Kuando Kubango technicians with other technicians included as a refresher course.

Course curriculum:	Theoretical and methodological aspects of hydrometric data collection
Instructor:	Paulo Emilio Mendez
Target audience:	Recently employed technicians
Course duration:	Two weeks
Approximate cost:	$5,000

1.32.2. Field Training - Cunene Province

The Manager of the Southern Regional Office, Antonio Pacheco Makete, is one of the most experienced hydrometric technicians in Angola. He has oversight responsibility for activities in Cunene, Huila, and Namibe Provinces. Five Thalimedes dataloggers are being installed on the Cunene basin either on the Cunene or its principle tributaries. The office also has at its disposal a vehicle and one of the two existing Vota multi-functional data processors used for downloading data from the Thalimedes dataloggers. Prior to installation of the Thalimedes equipment in Kuando Kubango, the Provincial hydrometric technicians should receive field training in the installation and use of the equipment by visiting the Southern Region and participating in data logger installation, data downloading and verification with Regional Office manager and selected technicians. This will provide an opportunity to familiarize technicians with the equipment and is operation before equipment is received and installed in Kuando Kubango Province.

Course curriculum:	Practical experience in installation and operation of equipment, developing current profiles and calculating discharge
Instructor:	Antonio Pacheco Makete and other technicians
Target audience:	New Kuando Kubango technicians
Course duration:	One month
Approximate cost:	$10,000 including field expenses

Computer Skills Training

The new hydrometric technicians will need to understand and use computerized equipment to download, evaluate, and store hydrometric data. Some of this equipment is associated specifically with the Thalimedes equipment, namely the VOTA data processor. However, data will need to be transferred to the OTT Hydras

software and saved in a format that allows data transfer to the HYDATA database in Luanda. Training in use of the Hydras software is specialized and should be included as part of the training provided by DNA staff. However, the technicians will need to understand basic computer concepts with more advanced training in the use of MS Word and MS Excel if possible. This training can be provided as part of computer skills development for other people involved with the Project or as part of regular course offerings by a computer training institute in Menongue.

Course curriculum:	Basic computer concepts and skills
Instructor:	To be determined
Target audience:	New Kuando Kubango technicians and others
Course duration:	Two weeks
Approximate cost:	$3,000

Field Installation, and Initial Discharge Measurement

Although the Kuando Kubango hydrometric technicians should have received methodological training and field training by the time the hydrometric instrumentation arrives in Kuando Kubango, equipment installation support should be provided. A the national agency providing guidance and support for hydrometric monitoring, Department of Water Resources should assist in installation and set-up of the Thalimedes instruments and participate in initial current profiling using the current meter to ensure acceptable work standards and to develop an initial velocity profile at each site. This will require that two DNA hydrometric technicians accompany the Kuando Kubango technicians as the five hydrometric stations are installed, current profiles developed, and discharge calculations completed.

Course curriculum:	Equipment installation and set-up, and initial discharge measurement
Instructor:	Antonio Pacheco Makete and another DNA technician
Target audience:	New Kuando Kubango technicians
Course duration:	Two weeks
Approximate cost:	$5,000 including field expenses

Follow-up Training and Support

In order to confirm that Kuando Kubango's hydrometric technicians are downloading data properly and completing the initial processing as required to calculate discharge at the five hydrometric stations, follow-up training should be provided. This should take place on at least three occasions with the Department of Water Resource's Manager for the Southern Region providing oversight, support and training as necessary by accompanying the technicians on their rounds as they collect data, enter the data into the computer, and generate basic analytical reports. This follow up should take place as the technicians make their second round of site visits to collect data, the fourth round, and on the anniversary of equipment installation.

Course curriculum:	Follow-up operations training
Instructor:	Antonio Pacheco Makete
Target audience:	New Kuando Kubango technicians
Course duration:	One week on three occasions
Approximate cost:	$1,500 including field expenses each occasion

APPENDIX 5: CONSULTANT SCOPE OF WORK

Title: Training Plan for Operating and Maintaining an Improved Hydrometric System

Activity: Visit national agencies responsible for water resources monitoring, describe current monitoring systems, identify gaps and training needs, and develop a training plan

Duration: Twenty-nine (29) days level of effort to be completed in Southern Africa between October 11 and November 12, 2005

Background

The USAID/OKACOM Okavango River Basin Project is a four-year initiative funded by the USAID/Southern Africa and supports the improved management of the Okavango River Basin, working with OKACOM as the major implementation partner. The Project addresses the USAID/Southern Africa objective to strengthen institutional, technical, and community capacity to manage the region's transboundary rivers.

The project comprises three components – strengthening OKACOM and its member states towards better management of river basins, enhancing information management systems to assist decision-making, and supporting community participation in river basin management and enterprise development. Incorporated with these three components are three cross-cutting themes – highlighting HIV/AIDS within the basin, ensuring the participation of women and disadvantaged groups, and promoting the participation of the private-sector, through the development of public private partnerships.

The Project has been operating since October 2004. During the implementation period, stakeholders have been engaged in validating the direction of the project, resulting in a life of project strategy and work plan that incorporates their opinions and suggestions. These include: the establishment of interim secretariat services for OKACOM and assisting towards establishment of a Permanent Secretariat, in collaboration with SIDA; design and installation of hydrometric monitoring stations in Angola; conducting socio-ecological surveys in Angola and assessment of CBNRM activities in Botswana and Namibia; and the preparation of a training action plan.

This consultancy supports the Component 2 activity: The design and installation of hydrometric monitoring stations in Angola. It complements and extends work already completed as part of the initial field reconnaissance and rapid assessment of the hydromet system in Angola.

Purpose

To define and review approaches to hydrological information collection, use and management in responsible institutions in each country (particularly as it relates to Okavango water resources information) and provide a training action plan for the project as part of the Project's contribution to improving water resource data systems.

A fundamental goal of the Project is to build local capacity. As general principles, the project will (a) maximize inclusion of local counterparts in all tasks assigned to senior consultants, and, (b) include representatives from all three riparian states whenever feasible. Therefore, the consultant shall perform all duties in a manner that maximizes transfer of skills and knowledge to a local counterpart in the Department of Water Affairs of each country, and transfer greater understanding of the skills and budgets required for operation and maintenance of the hydrologic network.

Activities and Tasks

The following activities and tasks will be completed under this SOW:

- Meet with Project COP, DCOP and USAID to confirm purpose, schedule, and deliverables;
- Visit two DWAs and DNA and interview staff to define national water resources programs and financial support, and how national hydrological data are collected, processed, analyzed, stored, retrieved, and used;
- Determine organizational structure for national agencies and institutional capacity to monitor water resources and part of the training needs assessment;
- To the extent possible, determine and describe the difficulties encountered in the process of collecting data and making it available for decision-making by national agencies and OKACOM;
- Identify specific constraints to sustainable operation and maintenance of existing national hydrological mentoring systems,
- Identify the requirements for hydrological data acquisition operation & maintenance and financing and determine whether constraints are related to organizational structure, budget, or technical skills;
- Determine what specific skills training is necessary for operating and maintaining the hydrological monitoring system,
- Identify national and regional organizations with the capacity to provide training required for sustainable operation and maintenance of national hydrological monitoring systems;
- With regard to the proposed hydro-posts in Kuando-Kubango Province, identify critical system elements that require support to ensure that systems are sustainable and data are available for decision-making;
- Prepare a training action plan for the hydrological monitoring system to include required training, proposed trainees, and training institutions. Special consideration will be given to the requirements for the proposed hydro-posts in Kuando-Kubango Province; and
- Prepare a briefing document for USAID and OKACOM Commissioners summarizing the findings and recommendations of the consultancy.

The consultant will ensure that skills are transferred to regional staff during the implementation of this Scope of Work. Primarily, he will ensure that staff from departments of water affairs are fully involved and learn from the activities. This training will introduce the staff to skills that they acquire during subsequent training courses.

Products/Deliverables

The product or deliverable of the Consultancy will be a report tentatively titled: A Water Resource Monitoring Training Plan for the Okavango Integrated River Basin Management Project. The report will include:

- A summary report description of current Okavango water resource data collection, analysis, and use in each country,
- Critical gaps in Okavango water resource information collection, analysis, and use,
- Requirements for sustainable operation and maintenance of proposed hydroposts in Kuando-Kubango Province, Angola, and
- A training action plan for Okavango water resources monitoring

APPENDIX 6: REPORT ON SPECIFIC TASK COMPLETION

The following activities and tasks were included in the Consultants scope of work. The following is an accounting of activities undertaken to complete these tasks.

Task 1: Meet with Project COP, DCOP and USAID to confirm purpose, schedule, and deliverables.

The consultant arrived on Sunday, October 9, 2005 and began working on Monday which was technically a holiday for USAID. The consultant met with the COP and DCOP on Monday, October 10. The briefing meeting with USAID was held on Wednesday afternoon, October 12th. USAID was represented by Keith Kline (the Project CTO), Wayne McDonald, and Rosalyn Waters-Jensen.

Task 2: Visit two DWAs and DNA and interview staff to define national water resources programs and financial support, and how national hydrological data are collected, processed, analyzed, stored, retrieved, and used.

This task was accomplished through a series of meetings with DWA-Botswana, DWA-Namibia, and DNA-Angola. A listing of persons met is included in Appendix 1. Discussions with these people informed sections of the country reports, most specifically the Institutional Setting section and the Instrumentation and Data Collection section of this report.

Task 3: Determine organizational structure for national agencies and institutional capacity to monitor water resources and part of the training needs assessment.

The organizational structure and institutional capacity to monitor water resources is described in the Institutional Setting sections of this report.

Task 4: To the extent possible, determine and describe the difficulties encountered in the process of collecting data and making it available for decision-making by national agencies and OKACOM.

The Findings section of each country report outlines difficulties encountered in the process of data collection and accessibility.

Task 5: Identify specific constraints to sustainable operation and maintenance of existing national hydrological mentoring systems.

Constraints to sustainable operations and maintenance are described in the Findings section of each country report.

Task 6: Identify the requirements for hydrological data acquisition operation & maintenance and financing and determine whether constraints are related to organizational structure, budget, or technical skills.

The requirements for hydrological data acquisition operation & maintenance and financing are included in the Findings section of each country report. An analysis of these constraints and recommendations are also included in the country reports.

Task 7: Determine what specific skills training is necessary for operating and maintaining the hydrological monitoring system.

A training action plan for Okavango River Basin water resources monitoring is included as Section 7 of this report.

Task 8: Identify national and regional organizations with the capacity to provide training required for sustainable operation and maintenance of national hydrological monitoring systems.

Selected regional and national organizations with the capacity to provide training are discussed in report Section 7: Proposed Training Action Plan

Task 9: With regard to the proposed hydro-posts in Kuando-Kubango Province, identify critical system elements that require support to ensure that systems are sustainable and data are available for decision-making.

This task was completed with the resulting report included as Appendix 4 of this report.

Task 10: Prepare a training action plan for the hydrological monitoring system to include required training, proposed trainees, and training institutions. Special consideration will be given to the requirements for the proposed hydro-posts in Kuando-Kubango Province.

A training action plan is included in this report in Section 7: *Proposed Training Action Plan*

Task 11: Prepare a briefing document for USAID and OKACOM Commissioners summarizing the findings and recommendations of the consultancy.

Due to the abbreviated session for Project reporting at the OKACOM meeting. A full briefing document was not required. The consultant did prepare a one page summary of the findings and recommendations of the consultancy for inclusion in the COP's Project report.

Task 12: The consultant will ensure that skills are transferred to regional staff during the implementation of this Scope of Work. Primarily, he will ensure that staff from departments of water affairs are fully involved and learn from the activities.

The consultant took every opportunity to work in close collaboration with the Senior Hydrologist and selected technicians with hydrometric monitoring responsibilities in each of the three countries. These opportunities provided the chance to ensure that these staff were fully involved in Project activities, describing local experiences and providing local perspectives on hydrometric data collection and use, and sharing their views on training needs and requirements. The Consultant took these opportunities to share his experiences and perspectives as a way to help these staff gain some perspective on their work. A one day visit to hydrometric stations at Rundu (Namibia) and Mohembo (Botswana) with the senior hydrologists from the three countries and subsequent meetings in Windhoek provided the Consultant a unique opportunity to pose questions that solicited valuable discussions regarding hydrometric monitoring in all three countries.

APPENDIX 7: RECOMMENDATION NOTES FOR THE OBSC MEETING, NOVEMBER 1, 2005

Following visits to Botswana, Angola, and Namibia, it is clear that the greatest training need is for Diploma-level technicians who oversee hydrometric data collection and non-Diploma technical assistants who perform much of the work in the field.

- Training is most critical in Angola particularly for new technicians to be assigned to Kuando-Kubango Province. Initial training focus should focus on these technicians.

- Basic instruction in hydrology and hydrometric monitoring for technicians is needed for technicians (Diploma level) and technical assistants (without Diploma). This is now provided largely through in-service training and OJT. Evaluation of specific training modules should be completed and shared among the hydrology divisions in each country so that these in-service programs can be improved.

- Accurate gauging is particularly important for determining flow rates. Joint gauging within the basin would provide valuable information as well as the opportunity for Acoustic Doppler Current Profiler (ADCP) demonstration and training. Joint gauging will also help convince all participants that flow data can be

- Technician cross visits with attention to installation, set-up, and use of the OTT Thalimedes water level data loggers is important as all countries are committed to or are seriously considering a move toward digital data collection. An initial opportunity for this type of cross visit will be the installation and set up of instrumentation in Angola.

There are other country specific training interests as follows:

Angola: English training, Flow measurement using the OTT C-31 Current meter (Molinette), and OJT to check and correct the work of younger technicians

Namibia: Motivation for Technical assistants that engender pride in doing a good result.

Botswana: Instruction for technical assistants in the proper instrument care and maintenance (current meters and chart recorders)

Final Note: The consensus of the Chief hydrologists (Mr. Mendez, Mr. Kalaote, and Mr. Langenhove), is that installation of equipment in Angola is the first priority. Mr. Langenhove had an impassioned plea, making the point that commitments were made in April and all were encouraged that things would actually happen. Now, at the end of October, it looks increasingly as if we will miss data collection for the upcoming rainy season. All agreed that civil works be completed and equipment procured with all possible haste.

APPENDIX 8: ANGOLA: MODERN GAUGING STATIONS AND CURRENT DNA STAFFING

1.33. CURRENT MODERN MONITORING LOCATIONS

HYCOS sites[34]

- Cabiri (Rio Bengo)
- Xangongo (Rio Cunene)
- Biopo (Rio Catumbela)
- Cachoeiras da Binga (Rio Queve)
- Luena (Rio Luena)
- Cambambe (Rio Cuanza)

Notes:
1: Information is stored locally in a memory module and transmitted via EUMET satellite to the Pilot Regional Center (PRC) at DWAF South Africa where data should be available at their internet site. Data are not currently being posted on the PRC web site.
2: SADC-HYCOS teams installed Cabiri and Xangongo, the remainder were installed with assistance of the NAWASMA project
3: Persistent problems with pressure sensors have plagued the HYCOS data logging units

OTT LogoSens datalogger with pressure sensor

- Km 34 (Rio Lucala)

OTT Thalimedes

- Bom Jesus (Rio Cuanza)
- Porto Quipire (Rio Dande)
- Quicombo (Rio Quicombo)
- Libongo (Rio Lifune)

Note: DNA has some 15 additional Thalimedes that are being installed with five allocated to the Cunene River and tributaries, four to the Catubela River and its tributaries and the remainder in various rivers in other coastal rivers

1.34. CURRENT STAFFING: DEPARTMENT OF WATER RESOURCES

Luanda Office

Paulo Emilio Mendes	Head of Water Resources
Francisco Quipuco	Georgapher and GIS specialist
Luzia da Concieçao	Economist
Francisco Fernando Miguel	Chief Technician, Hydrometry and Manager for Central region (Luanda, Cabinda, Bengo, Cuanza-Norte

[34] Equipment provided under the SADC-HYCOS Phase I program

Narciso Agusto Ambrosio	Hydrometry, data management, and electronics
Edsom Francisco Joaquim Miguel	Hydromaery and Mapping
Eliza Machado	Department Secretary

Field Offices

Cunene Province (Xangongo)

Antonio Pacheco Makete	Chief Technician, Hydrometry Manager for South Region Hydrometry Unit Cunene Province and (Cunene, Huila, and Namibe Provinces) and Head of the Provincial Water Department

Huila Province (Lubango)

Jose Machel da Silva Isaias	Hydrometry, works under the direction of Hydrometry Manager South Region
Pedro Henda Castro	Hydrometry, works under the direction of Hydrometry Manager South Region

Benguela Province (Benguela)

Waldo Pinto Rocha	Hydrometry responsibility for Benguela, Huambo, and Cuanza Sul, works under the direction of Hydrometry Manager South Region
Antonio Pascal Natal Sajujole	Hydrometry responsibility for Benguela, Huambo, and Cuanza Sul, works under the direction of Hydrometry Manager South Region

Notes:
1: All staff not located in Luanda are managed by Antonio Pacheco Makete
2: All Hydrometry staff (8 in total) received training in South Africa under the NORAD financed NAWASMA project
2: No current hydrometry coverage in eastern provinces of Lunda Sul, Lunda Norte, Cuando Cubango, Moxico, Zaire, Malange, Bie, Huambo, and Uige.